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Field sprayers for pesticides

Canada

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Field sprayers for pesticides

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Recommendations for pesticide use in this publication are intended as guidelines only. Any application of a pesticide must be in accordance with directions printed on the product label of that pesticide as prescribed under the Pest Control Products Act. **Always read the label.** A pesticide should also be recommended by provincial authorities. Because recommendations for use may vary from province to province, your provincial agricultural representative should be consulted for specific advice.

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INTRODUCTION

The use of pesticides is an integral part of modern agricultural production systems. Pesticides are used widely to control weed, insect, and disease pests. The effectiveness of a pesticide (herbicide, insecticide, or fungicide) or a plant growth regulator depends on the following:

- applying it at the proper rate and volume
- spraying the pest at its most susceptible stage (i.e., proper timing)
- using properly the correct type of application equipment.

The high cost of pesticides, the introduction of new pesticides requiring extremely low rates of application, and the increase in environmental concerns regarding the use of pesticides require that all application equipment be of the highest quality available, properly used, and maintained.

Pesticides applied incorrectly may result in poor control and cause damage to susceptible crops. Application overlaps of persistent pesticides may also damage succeeding crops. The use of pesticides without due caution and protective equipment and clothing may result in serious health hazards. The improper storage and handling of pesticides and improper disposal of empty containers may result in serious environmental hazards.

This publication contains information on the various types of sprayers, their components, and their efficient use. Other sections cover sprayer maintenance, drift control, and safety and health concerns. Readers should also refer to the bulletins and publications listed under "Additional information" at the back of this booklet.

TYPES OF SPRAYERS

The most common sprayer is the low-pressure, broadcast boom sprayer. Therefore, most of this publication is devoted to its components and use. This sprayer generally has tapered edge, flat spray nozzles mounted on a wet boom at 50-cm spacings, which will provide a uniform spray pattern when operated at the optimum pressure and height.

Sprayers used for row-crop application may have the nozzles mounted on rubber hoses or drop pipes clamped onto a dry boom. The nozzles are adjustable along the boom frame for various row spacings. Row-crop sprayers are generally equipped with nozzles fitted with even flat spray tips to apply even bands of pesticide without overlapping. For applying insecticides or fungicides, cone-type nozzles are commonly used on row-crop sprayers.

Boomless sprayers are generally used for spraying pesticides in pastures, on roadsides, and in other areas where rough terrain prevents access with a boom sprayer. They can also be used to apply

insecticides to field perimeters and grasslands. Their use for the application of herbicides on cropland is *not* recommended because of uneven spray patterns and potential for drift.

Small sprayers, either hand-operated or vehicle-mounted, are useful for spot treatment in fields, for spraying lawns, and for spraying areas that are inaccessible by larger equipment.

Air-blast sprayers are used almost exclusively for applying insecticides and fungicides in orchard and vegetable crops, whereas foggers of various types are used for controlling mosquitos and flies, both indoors and outdoors.

HAND-OPERATED SPRAYERS

Compressed-air sprayers

Nearly all hand-held sprayers are of the manually operated, compression-tank type. An internal or external compression pump is an integral part of the sprayer. Spray can be discharged onto the target for only a short time before the tank pressure drops and the operator must stop and pump it up again.

Most compressed-air sprayers come equipped with an adjustable nozzle that delivers fine-to-coarse spray in either a cone-shaped pattern or a solid stream that may reach 3–5 m.

Knapsack sprayers

A typical knapsack sprayer (Fig. 1) has a tank capacity of 8–20 L. Continuous hand-pumping keeps the sprayer operating by forcing the liquid out via a small surge chamber. Air pressure is retained briefly in the surge chamber, but spray delivery drops quickly when pumping stops.

A knapsack sprayer permits an operator to handle larger volumes of spray liquid with more ease than with hand-held, compressed-air sprayers. Thus, knapsack sprayers are adapted for larger jobs.

On some models the pump handle can be switched to either side of the sprayer, which is a benefit when spraying large areas.

Stainless steel, galvanized steel, and brass have been the predominant materials used for sprayer construction. Plastic units have gained popularity more recently because of their resistance to corrosion and their light weight. Being able to see the liquid level through the plastic tank is an added convenience.

Some wettable powder pesticides settle out rapidly in water, posing a problem with hand-operated sprayers that have no provision for agitation. Shaking the tank periodically during use helps to prevent the pesticide from settling in the tank.

A trial run with water in the tank while spraying a measured area indicates how much area one tankful of solution will cover.

Fig. 1 Knapsack sprayer.

Fig. 2 Push-type sprayer.

Fig. 3 Tractor-mounted sprayer.

Fig. 4 High-clearance sprayer.

Push-type sprayers

Push-type, hand-operated sprayers (Fig. 2) are useful for treating large lawns. They usually have a tank capacity of 15–25 L and apply a swath of pesticide 1–2 m wide.

One type uses gravity to carry the solution down to a spinning disc. At normal walking speed, the disc, driven by a ground wheel, disperses the spray in a swath about 1 m wide. The height of the spray disc is fixed, which restricts the use of this sprayer to mowed areas.

Another push-type sprayer operates at low pressure supplied by a hose pump consisting of a flexible piece of tubing stretched over a roller reel. The reel driven by the ground wheel of the sprayer causes each roller to squeeze the tubing, creating a vacuum that draws the spray solution from the tank. The next roller squeezes the solution along the tubing to the spray nozzles. Nozzle height is adjustable.

ALL-TERRAIN VEHICLE (ATV) MOUNTED SPRAYERS*

These sprayers usually use a 12-volt electric pump powered by a battery.

The pump delivers about 5 L/min at 200 kPa pressure. A short boom and a handgun allow spraying of weeds or trees for insect control.

TRACTOR-MOUNTED SPRAYERS

Tractor-mounted sprayers have tanks of 500–2000 L (Fig. 3). The pump may either be attached directly to the power take-off (PTO) shaft of the tractor or be driven by a hydraulic motor. Booms may be mounted in the front, rear, or, in some cases, the belly position for broadcast application with a nozzle cluster. The boomless type of application is useful for rough terrain. Tractor-mounted units are sometimes combined with other equipment such as planters, cultivators, or tillage implements for row-crop application.

Sprayers are sometimes mounted on the chassis of a self-propelled windrower or other farm equipment. Tank size is limited by the weight that the chassis can carry.

HIGH-CLEARANCE SPRAYERS

High-clearance sprayers (Fig. 4) have evolved from tractor-mounted sprayers and are used for spraying row crops. The tank is usually underslung and fits between crop rows. The spray boom is adjusted for crop height and application requirements. Adjustable

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* *CAUTION*: This type of sprayer is not suitable for wettable powder formulations unless sufficient agitation is provided.

axles allow spraying in a wide variety of row spacings with wheel shields preventing damage to low-hanging crops.

TRAILER-MOUNTED SPRAYERS

The towed, trailer-mounted sprayer (Fig. 5) is the most common type of sprayer. Tank capacity may be as large as 4000 L, and booms may exceed 35 m in length. Pumps are mounted either on the tractor or sprayer and are driven either by the tractor PTO or by a hydraulic motor; some sprayers have pumps driven by the sprayer wheel. These sprayers are used to apply most pesticides in cereal and oilseed crops, and the nozzles are usually mounted 50 cm apart on either a wet or dry boom.

A variety of small, trailer-mounted sprayers are commonly used by estate owners, industrial institutions, and farmers having large lawns. These sprayers may be equipped with either a 12-volt electric pump or a PTO pump. Handguns are supplied for spraying trees to control insects or diseases.

TRUCK-MOUNTED SPRAYERS

Sprayers may be mounted on skids for use in pick-up or flat-bed trucks (Fig. 6). An auxiliary engine supplies power for the pump; tank size is limited by the size of the truck. Booms are used in crop spraying but may be detached when spraying pastures, roadsides, or other sites too rough for field-size booms. Some models of truck-mounted sprayers have booms that fold up for transport.

Larger sprayers have tanks holding up to 10 000 L and are mounted on large trucks for roadside spraying to provide brush and weed control or for spraying other rights-of-way, such as pipelines and power lines. These sprayers are generally equipped with a piston or diaphragm pump to provide high pressures for handgun use. However, excessive pressure increases the potential for drift and is not generally recommended for applying herbicides.

Various hydraulically controlled booms are used by municipalities for roadside spraying. Some sprayers use off-centre, single- or double-swivel nozzles, or special nozzles to reduce spray drift, as a boomless type of spraying system. Boomless systems are less costly than hydraulic articulating booms. However, the distribution of spray is not as uniform and is prone to drift. It is difficult to keep truck speeds constant, and the use of rate monitors or automatic rate controllers with truck sprayers is recommended.

SELF-PROPELLED SPRAYERS

Large, self-propelled sprayers (floaters) have low-pressure flotation tires (Fig. 7). These tires do less damage to crops than

Fig. 5 Trailer-mounted sprayer.

Fig. 6 Truck-mounted sprayer.

Fig. 7 Large, self-propelled sprayer.

normal-width tires and allow operation under adverse soil conditions. Because of their high initial cost, they are suitable only for very large farms or custom operators. Some units have tank capacities as high as 10 000 L. Dust created by the large tires at high speeds sometimes results in poor weed control. Therefore, avoid excessive speeds when applying post-emergent herbicides.

Smaller, self-propelled sprayers (Spra-Coupe) (Fig. 8) are sometimes used to apply low volumes. Lower volumes increase the potential for spray drift. Higher-capacity tanks and nozzles with lower boom heights are available on newer models. These sprayers have a high-clearance frame and adjustable tread, which allows spraying of insecticides and fungicides at later crop stages. These sprayers can also be used for row-crop spraying.

AIRCRAFT SPRAYERS

The chief advantages of aircraft sprayers relative to ground equipment are the following:

- application can be made in places where ground equipment cannot operate
- applications can be done more quickly
- soil compaction and crop damage is eliminated
- no capital investment is required by the farmer, if custom applicator is available.

Among the disadvantages, consider the following:

- cost of application is higher than with ground rigs
- drift potential is greater, leading to more restrictions on wind conditions, and limiting the time available for spraying
- small fields cannot be sprayed from the air
- limited number of pesticides are approved for aerial application
- proper calibration and operation is essential, because aircraft sprayers do not apply pesticides as uniformly as ground rigs. Careful evaluation and adjustment of each aircraft is required to ensure uniform application.

Although helicopters are more maneuverable than fixed-wing aircraft and are not restricted to operating from a landing strip, they are more costly to use and carry a smaller payload than fixed-wing units.

AIR-BLAST SPRAYERS (MIST BLOWERS)

An air-blast sprayer uses air as a carrier for spraying of liquids (Fig. 9). Combining air and water as carriers for the pesticides permits a higher concentration of spray material to be applied on more area per tankful. The air-blast sprayers are used on orchard crops, grapes, raspberries, blueberries, hops, evergreen trees, and various types of vegetable crops.

Hollow-cone nozzles are commonly used on air-blast sprayers. The selection of the correct nozzle tip and swirl plate will provide the required combination of droplet size and spray volume.

The density of the crop, together with the weight of the leaves and thickness of the stem, determines the speed and volume of air necessary for good penetration. This requirement changes with different crops and with their stage of development.

Another factor, especially when spraying grapes, berry bushes, and vegetables, is the bouncing effect the air has on a very dense leaf mass. Because all crops try to expose the leaf surface to the sun, it can be difficult to get thorough penetration and coverage of all leaves. Some sprayers are equipped with adjustable outlet spouts. Best results have been obtained by adjusting these spouts 30–45° backwards from the direction of travel. Another important factor for good penetration is travel speed, which should not exceed 7 km/h when spraying with an air-blast sprayer.

Lightweight, portable foggers are used both indoors and outdoors to dispense insecticides for mosquito and fly control. These units are also used for applying materials used for abating noxious odors. Some manufacturers offer kits that allow motorized knapsack sprayers to be used for fogging.

OTHER APPLICATION EQUIPMENT

Wiper applicators

A weed control technique, used on a limited scale, is the use of height-selective applicators. To achieve selective control, this technique relies on a height difference between the crop and the weed. Generally, the weeds must be at least 15 cm above the crop. Various types of applicators are available, which can be used in row-crop situations and where tall weeds affect crop production.

Roller applicator

This unit has a rotating roller that is carried above the crop (Fig. 10). A herbicide, applied to the roller, is wiped onto the weed growth above the crop.

Rope-wick applicator

This machine (Fig. 11) operates similarly to a roller applicator. However, the roller is replaced by a pipe containing herbicide and fitted with pieces of rope that are wetted with herbicide through capillary action. The rope wipes herbicide onto the weeds growing above the crop.

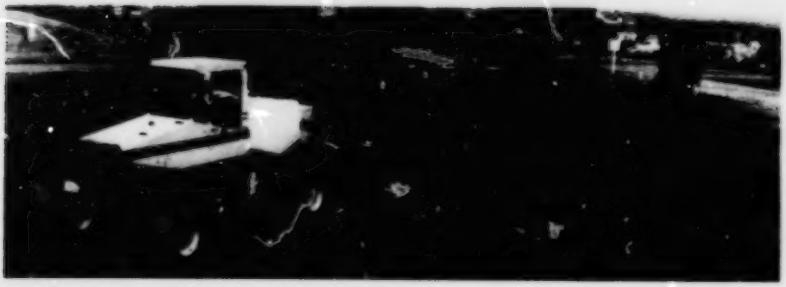

Fig. 8 Small, self-propelled sprayer.

Fig. 9 Air-blast sprayer.

Fig. 11 Rope-wick applicator.

Fig. 10 Roller applicator.

Hand-held wipers

Hand-held wipers (Fig. 12) are generally constructed of a plastic pipe shaped like a hockey stick with a rope or ropes mounted on the blade portion. The rope is connected into the pipe to allow the herbicide solution in the pipe to wick through the rope to be wiped onto the vegetation.

This type of weed wiper was designed for the home and garden situation to treat smaller areas and remove unwanted growth (roguing) near desirable vegetation. The herbicide will control only those plants that are directly contacted by adequate amounts of solution. Repeat treatments will be necessary to control vegetation that was not contacted or did not receive sufficient contact during the initial treatment.

All these systems have advantages and disadvantages. The advantages are as follows:

- selectivity can be achieved using nonselective herbicides
- smaller quantities of herbicides are applied, reducing herbicide use, cost, and soil residues
- drift to adjacent areas is reduced.

The disadvantages are as follows:

- level of control is less than with conventional spraying
- low-growing weeds are not controlled
- weeds are controlled later in the season, after considerable competition has taken place
- new equipment is required
- travel over advanced crop may cause yield losses.

Height-selective applicators are normally used as a supplement to current methods for weed control, primarily to clean up weeds that have escaped control or to control patch infestations of perennial weeds. Row crops, which allow later-season traffic without trampling the crop, and control of weeds in forage crops are other areas where height-selective applicators are useful.

Controlled-droplet applicators

Controlled-droplet applicators (CDA) or spinning-disc sprayers (Fig. 13) are usually trailer-mounted, but can be tractor-mounted as well. These sprayers have a number of electrically or hydraulically driven spinning discs mounted at 1-m intervals along the boom (Fig. 14). Spray solution is metered onto the spinning discs, and droplets are formed by centrifugal force as the spray solution is emitted horizontally or vertically. The size of droplets formed in this manner depends on flow rate of the solution and the speed at which the disc spins. The droplet size spectrum of some CDAs is quite narrow. Adjustment of disc speed and flow rate produces droplets of different sizes. Droplets of 150–250 μm in diameter are usually

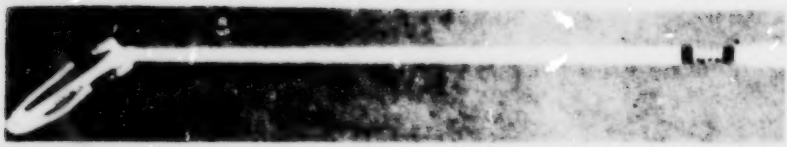

Fig. 12 Hand-held wiper.

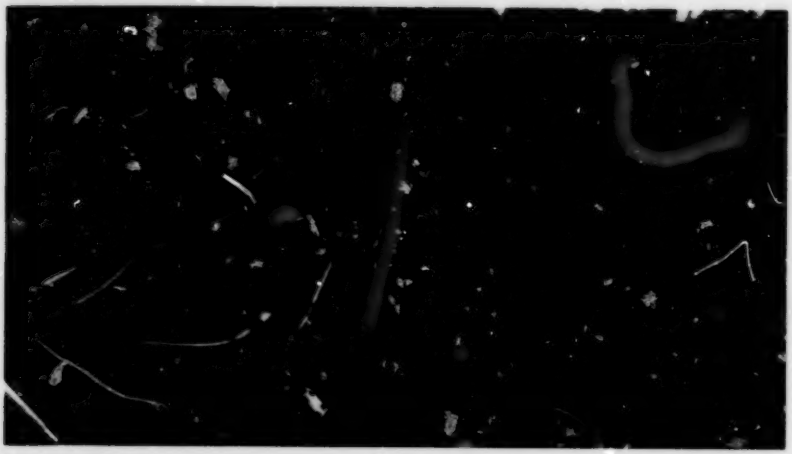

Fig. 13 Spinning disc sprayer.

Fig. 14 Close-up of a spinning disc driven by an electric motor.

preferred for providing desirable plant coverage and drift resistance. However, recent studies have shown that the spinning-disc sprayers produce more drift than a conventional sprayer and that their deposit pattern is also more variable. Depending on the size of the discs, a disc speed of about 2500 rpm is usually used. CDAs are best suited for low-volume applications (25–30 L/ha).

Air-assisted sprayers

Air-assisted sprayers (Fig. 15) are truck- or trailer-mounted sprayers that use venturi-like air passages (grommets) instead of nozzle tips (Fig. 16). These grommets are spaced at about 17 cm along the dry boom. Solution under very low pressure (about 40 kPa) is carried through hoses to an airfoil-shaped emitter located within the grommets. A large, PTO-driven fan blows air through the booms, and the air flowing over the airfoil causes the thin layer of liquid emitted to break into droplets at the rear edge of the airfoil and carries the droplets to the plant canopy. These sprayers produce tiny droplets (< 100 µm), which can be prone to drift. Air-assisted sprayers work best when applying low volumes of spray solution (about 25 L/ha), and when penetration of the canopy is desirable.

Electrically charged sprays

A different approach employed to reduce drift and to increase plant coverage and canopy penetration is to charge the spray droplets electrically. The solution is given a slight positive charge before it is emitted from the nozzles or discs. Because plants and the ground are slightly negatively charged, the spray droplets are attracted to them. Theoretically, this system enables one to apply low volumes of solution containing tiny droplets (< 100 µm) that are not prone to drift.

SPRAYER COMPONENTS

To deliver pesticide to the target, components must operate together efficiently to perform the following basic functions:

- hold and transport pesticide and water, mixed or separately
- meter both pesticide and water
- distribute a mixture of pesticide and water in the correct manner and rate to the target.

The kind and number of components depend upon the sprayer size and on the complexity of control and monitoring devices used to assist the operator. Components must be chosen carefully and matched to provide optimum performance.

Fig. 15 Air-assisted sprayer.

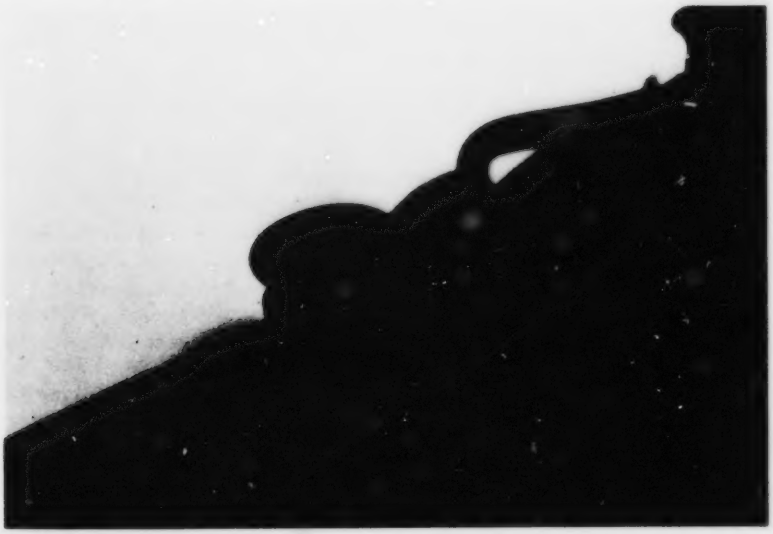

Fig. 16 Close-up of a grommet assembly for an air-assisted sprayer.

TANKS

Sprayer tanks are available in a variety of shapes, sizes, and materials. Avoid square tanks and tanks with flat bottoms because proper agitation and cleaning are difficult. The most popular shapes are the oval tank and the horizontal cylindrical tank. Spherical tanks are less common but have an additional advantage for agitation and emptying. Tank size should be proportional to sprayer width, intended application volumes, and acceptable refilling intervals. Too

small a tank takes more time for spraying because of frequent refilling, which reduces efficiency. Larger tanks reduce the number of stops but require a sturdier and heavier sprayer undercarriage and may contribute to crop damage and soil compaction.

The tank must have a large opening of 30–45 cm, conveniently located for filling, cleaning, and inspecting. The opening should be splash-proof, have a vented lid, and be fitted with a 80 or 100 mesh screen. Tank lids should be fastened securely to prevent small children from entering when the sprayer is idle.

The drainhole must be located in the lowest part of the tank bottom for complete draining. Tanks with inlets for bottom filling are useful for pesticide loading systems and for mixing the pesticide with water. A gauge with accurate, easy-to-read capacity markings is essential for determining the level of the liquid.

Sprayer tanks are made of stainless steel, polyethylene, fiber glass, aluminum, and galvanized steel. Mild steel and galvanized steel are not recommended because they corrode readily. The operator should check the pesticide labels for any precautions and instructions regarding acceptable tank materials.

Stainless steel

Stainless steel is the highest-quality material for sprayer tanks and is strong and resistant to corrosion by pesticides. Lower grades of stainless steel and welds used in fabrication may develop rust stains but, aside from the appearance, these do not usually cause any serious problems.

Polyethylene

Polyethylene tanks are made of a broad range of synthetic materials that are generally resistant to corrosion from pesticides. Fabrication methods have resulted in tanks that are tough, durable, and available in various shapes and sizes. Store these tanks indoors to avoid any potential deterioration of the materials by sunlight. Most polyethylene tanks may be repaired by hot-air welding. Provide proper structural support for these tanks to avoid high-stress areas.

Fiber glass

Fiber-glass tanks are widely used on all types of sprayers and as nurse tanks. Fiber glass is strong and durable but will crack or break under sharp impact. On-farm repair kits are available for minor repairs. Some types of solvents may affect fiber-glass tanks. Provide proper structural support for these tanks to avoid high-stress areas.

Aluminum

Aluminum tanks are medium in cost, resistant to corrosion, and suitable for many pesticides. Laboratory tests have shown that the herbicide TCA has some chemical reaction with aluminum. However, if the tank is cleaned immediately after use no problems should arise.

Galvanized steel

These tanks are less expensive than stainless steel but are subject to corrosion. Even with protective coatings, some pesticides cause rapid deterioration. Rust flakes off, plugs tips, clogs strainers, and can damage pumps. Galvanized tanks, although suitable for most pesticides, should not be used with the more corrosive liquid fertilizers.

UNDERCARRIAGE

The undercarriage of a sprayer not only carries the weight of the tank and contents but also provides the main support for the booms.

Sprayers with large tanks should have an adequate number and size of wheels to provide flotation and to reduce boom oscillations. The tandem axle or walking-beam axle arrangement for the chassis and booms, with wheels following in the same track, lessen the area of compaction and crop damage. The walking-beam axle also provides a smooth, steady support for the booms, helping to maintain an even height above the target; boom wheels with shock absorbers are also effective. Low-pressure flotation tires also provide a smooth ride for both sprayer and booms.

The amount of crop damage caused by tractor and sprayer tires varies and is difficult to assess. Although plants may be killed in tire tracks, the effect on yield is often negligible, where soil moisture limits yield as on the prairies. Prairie Agricultural Machinery Institute (PAMI) tests indicate that both flotation tires and tandem wheels are effective in reducing compaction and boom movement. Trampling from the sprayer amounts to less than 2% of the field area, and most of the crop usually recovers.

Trampling by the tractor may be greater with dual wheels, but increased flotation and reduced slippage are an advantage in soft or loose soil. Small tractors that have high tire slippage can tear out all plants beneath the tires. Generally, little crop loss is caused by sprayer tires, but high-speed turns and slippage of tractor tires may cause minor damage.

Mounted or self-propelled sprayers also use various boom support systems to maintain even boom height and to reduce oscillation, including boom outrigger wheels. Truck chassis must be able to carry a full tank and therefore truck size should be between 3/4 and 1 tonne or larger, with appropriate tires.

PESTICIDE TRANSFER

Pesticides may be transferred from containers by an induction system. Many newer sprayers are equipped with a separate tank conveniently located to enable pesticide to be poured in from ground level. The pesticide is transferred from this tank to the sprayer tank as it fills with water, ensuring good mixing. Some sprayers have a suction wand that can be inserted directly into pesticide containers. Both methods require care in transferring the correct amount of pesticide, but each is more convenient and safer than pouring pesticide directly into the sprayer tank.

Hand-operated pumps can also be used to transfer pesticide from containers to the sprayer tank.

AGITATORS

The amount of agitation needed depends on the type of pesticide used and the size of the tank. Liquid concentrates and emulsions require little agitation whereas wettable powders require intense agitation to prevent settling. Agitation may be provided by mechanical agitators (Fig. 17*A*), driven by electric or hydraulic motors, internal combustion engines, or PTO.

Hydraulic agitation is more common as it uses excess pump capacity, which, when passed through a "volume-booster" (jet agitator) or sparge tube (Figs. 17*B*, *C*), provides ample agitation for most conditions. Jet agitators are available in a variety of sizes with output volumes up to two-and-a-half times the input volume. To control the amount of agitation, a control valve must be installed in the supply line. An agitator must not be connected to the bypass line.

Hydraulic agitation tank kits are available from farm service outlets, for installation in existing field sprayers. Ensure that the pump has sufficient capacity for the addition of an agitator (refer to section on "Pumps, capacity").

PUMPS

The pump creates the flow and pressure required to atomize the spray and to agitate the tank contents hydraulically. Select the pump to provide adequate volume and pressure capability for each spraying requirement (Table 1). Ensure that it is equipped with proper seals compatible with the pesticide being used. Consult the manufacturer's literature for this information. Sprayer pumps are available in several types: roller, centrifugal, turbine, piston, and diaphragm. Gear and flexible impeller pumps have been used but are not common because of high rates of wear.

Table 1 Capacities of some common sprayer pumps

Pump	Model	Type	Drive	Output @ 275 kPa
Ace	FMC-HYD-XXX	centrifugal	hydraulic	190 L/min —
	FMC-200-HYD	centrifugal	hydraulic	304 L/min —
	PTOC	centrifugal	PTO	190 L/min @ 1000 rpm
	PTOCH	centrifugal	PTO	230 L/min @ 1000 rpm
Delavan	Turbo-90	centrifugal	PTO	125 L/min @ 1000 rpm
	34945	centrifugal	hydraulic	140 L/min —
	35566	centrifugal	hydraulic	170 L/min —
	46818-1	centrifugal	hydraulic	200 L/min —
Demco	TCS	centrifugal	PTO or hydraulic	190 L/min @ 1000 rpm
Hypro	Series 9006	centrifugal	PTO (gear)	375 L/min @ 3780 rpm
	Series 9008	centrifugal	— (gear)	400 L/min @ 4000 rpm
	Series 9401	centrifugal	— (belt)	196–300 L/min @ 6000 rpm
	Series 9300	centrifugal	hydraulic	340 L/min —
Hypro	Series 60	diaphragm	PTO	60 L/min @ 540 rpm
	Series 100	diaphragm	PTO	100 L/min @ 540 rpm
	Series 150	diaphragm	PTO	150 L/min @ 540 rpm
Delavan	55-0000	roller	PTO	80 L/min @ 540 rpm
	66-0000	roller	PTO	33 L/min @ 540 rpm*

(continued)

Table 1 Capacities of some common sprayer pumps (*concluded*)

Pump	Model	Type	Drive	Output @ 275 kPa	
	77-0000	roller	PTO	50 L/min @	540 rpm*
	88-0000	roller	PTO	43 L/min @	540 rpm*
Hypro	Series 1200	roller	PTO	189 L/min @	540 rpm
	Series 1500	roller	PTO	110 L/min @	540 rpm
	Series 1700	roller	PTO	85 L/min @	540 rpm
	Series 7560	roller	PTO	42 L/min @	540 rpm
	Series 7560	roller	PTO	80 L/min @	1000 rpm
	Series 7700	roller	PTO	50 L/min @	540 rpm
	Series 6500	roller	PTO	30 L/min @	540 rpm
	Series 6500	roller	PTO	65 L/min @	1000 rpm
Lurmark	RV 10	roller	PTO	40 L/min @	540 rpm
	RV 25	roller	PTO	110 L/min @	540 rpm
	RV 35	roller	PTO	180 L/min @	540 rpm
Hypro	Series 5210	piston	PTO	40 L/min @	540 rpm
	Series 5425	piston	PTO	88 L/min @	540 rpm
LIL	Thumper	piston	ground	27.8 L/min @	100 rpm
	Thumper	piston	ground	55.7 L/min @	100 rpm

* Double outputs for 1000 rpm.

Note: Hydraulic drive centrifugal pumps must be matched to the tractor's hydraulic system. Consult the dealer regarding hydraulic specifications and limitations.

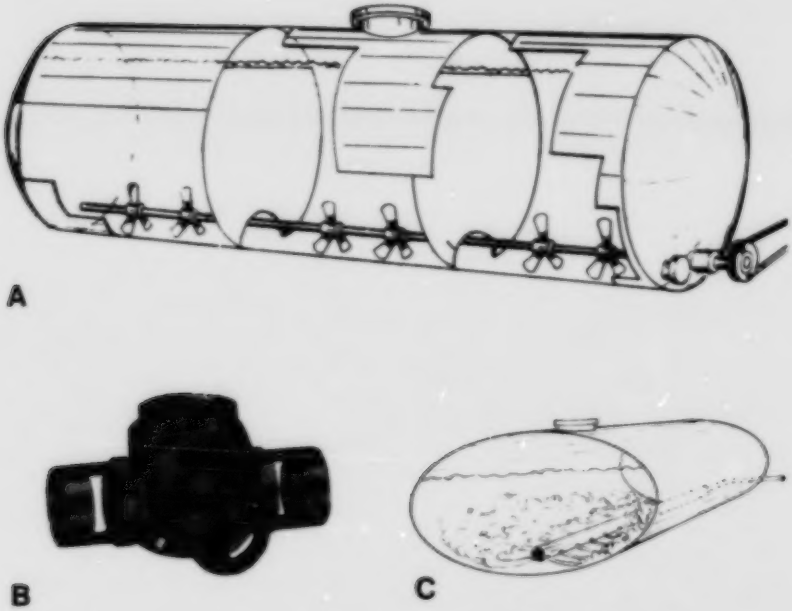

Fig. 17 Agitators: (*A*) mechanical agitator, (*B*) jet agitator, (*C*) sparge tube.

Fig. 18 Roller pump.

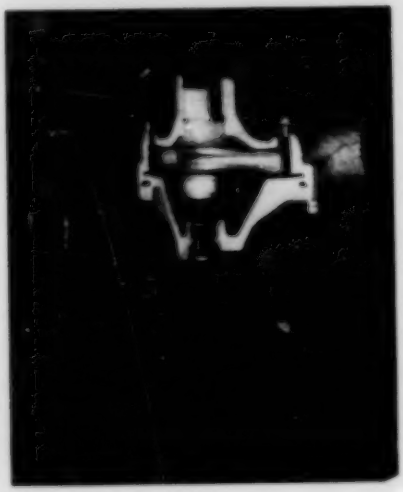

Fig. 19 Centrifugal pump.

Types

Roller pumps

Roller pumps (Fig. 18) are commonly used because of their lower cost, compact size, and ease of repair. They operate at 540–1000 rpm and are available in a wide range of capacities for different sizes of field sprayers. Roller pumps can be used to pump water and most pesticide solutions including wettable powders, although wettable powders and other abrasive materials will cause faster wear of the rollers and housing. Make sure that the roller material is compatible with the solution being pumped. Never run a roller pump dry, as the fluid is the lubricant.

Centrifugal pumps

Centrifugal pumps (Fig. 19) require high rotational speeds that can be provided with a step-up drive from a tractor PTO or with a hydraulic motor. Take care to select the appropriate motor to suit the tractor hydraulic system. The impeller speed of the pump is normally between 3000 and 4500 rpm but may be as high as 6000 rpm.

Centrifugal pumps have ample capacity for most sprayer applications and are capable of handling most types of pesticide solutions, emulsions, and wettable powders. The centrifugal pump's main disadvantage is that pump output and pressure decrease rapidly with small reductions in pump speed. Maximum output pressures are 300–400 kPa, which are adequate for most field spraying but may be insufficient for some special applications.

Turbine pumps

Turbine pumps have similar characteristics to centrifugal pumps but run at a lower speed, about 1000 rpm. As centrifugal and turbine pumps are nonpositive displacement pumps, use a control valve instead of a pressure regulator to regulate the output pressure.

Piston pumps

Piston pumps (Fig. 20) are suitable for most pesticides and are designed primarily for high-pressure spraying applications up to 4200 kPa and for pumping wettable powders and abrasive liquids. These pumps may be driven from the PTO or by an engine. Select the pump model appropriate to the drive application. Use a pressure accumulator to dampen the pressure surges between piston strokes.

Fig. 20 Piston pump.

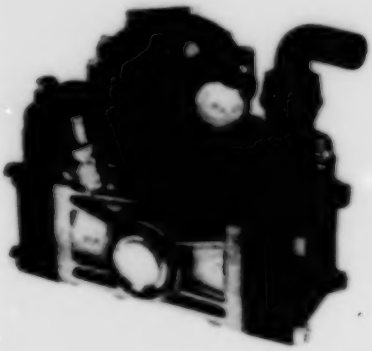

Fig. 21 Diaphragm pump.

Ground-driven piston pumps

Ground-driven piston pumps are used on some sprayers. When the ground speed changes, the pump output changes proportionately, so that the application rate remains constant. This type of operation is satisfactory for obtaining proper spray patterns and overlap provided the speed change is not more than 15%. Use separate pump to provide tank agitation.

Diaphragm pumps

Diaphragm pumps (Fig. 21) are available in a variety of pressure and output capacities. They are resistant to wear from abrasive solutions. Pulsation dampers are necessary to reduce pressure fluctuations.

Material

Regardless of what type of pump is used, check that pump parts coming into contact with the pesticide are made with chemical- and corrosion-resistant materials. Metals, such as Ni-Resist castings, are higher priced than cast iron but have higher resistance to corrosion. Seals and other parts must also resist any effects from the pesticide and water mixture.

Capacity

Determine the required pump capacity (Tables 1 and 2) by using the highest volume application, sprayer width, and speed of application in the following formula:

$$\text{pump capacity (L/min)} = 1.2\left[\frac{\text{speed (km/h)} \times \text{width (m)} \times \text{volume (L/ha)}}{600} + 1.5\% \times \text{tank size (L)}\right].$$

This capacity allows for wear and agitation. If wettable powders are to be used, increase the 1.5% of tank size to 3%.

Pump capacity check

Pump capacity may be checked as follows:

1. Perform tests using water (without added pesticide) to avoid unnecessary handling of hazardous materials.
2. Direct the total pump output, at rated pump speed and pressure, through the bypass line into a container of known volume. With a roller pump system, shut off the boom lines and agitator line, disconnect the bypass line from the tank, and direct its flow into a container. Set the pressure regulator to normal operating spray pressure. With centrifugal pumps, shut off the boom lines, and direct the agitator line into the container. Use throttling valve to adjust the pressure. Measure pump capacity with normal fittings and filters in place and at the pressure used for spraying.
3. Determine the time required to fill the container.
4. Calculate:

$$\text{pump capacity (L/min)} = \frac{\text{volume collected (L)}}{\text{time (min)}}$$

PRESSURE CONTROL

Controlling pressure on a sprayer is essential to its overall operation. The pressure control system regulates the operating pressure, which governs nozzle tip output and spray angle. On sprayers with ground-driven piston pumps, the pressure varies as the speed is changed.

Manual regulators

The pressure relief-regulating valve (Fig. 22) is commonly used to control and adjust pressure on sprayers equipped with roller, piston, and diaphragm pumps. On sprayers equipped with a centrifugal pump, a gate or globe valve may be used to control the pressure.

On sprayers using high pressures (>1400 kPa), or on those in which the liquid flow is shut off frequently, use an unloader valve

(Fig. 23). An unloader valve opens hydraulically and allows pump output to flow back to the tank at a set pressure, which helps guard against sudden pressure surges caused by shutting off the sprayer.

Electronic regulators

Electronically controlled regulating valves (Fig. 24*A*), including devices for their remote control (Fig. 24*B*), are available. These valves are commonly used in conjunction with manually controlled pressure regulators to provide remote fine-tuning of pressure.

Pressure gauge

An accurate pressure gauge is needed to ensure that the proper application rate and spray pattern is being produced. Keep a spare gauge on hand in case of failure and for checking boom pressure.

Pressure gauges should have a total range of twice the maximum reading expected. Gauges reading 0–450 kPa or 0–700 kPa are satisfactory for most field spraying. Check gauges at least yearly for accuracy. If in doubt, replace the gauge, as it is not an expensive item. Install a gauge that is large enough to be easily seen and that is equipped with a pressure damper to reduce vibration of the gauge needle. Liquid-filled gauges that serve to dampen pulsations are required when using piston or diaphragm pumps.

Pressure gauge check

Pressure gauge accuracy may be checked as follows:

Method I

1. Attach a hose equipped with a tire chuck to the sprayer pressure gauge (Fig. 25).
2. Inflate a tire to 250 kPa being sure to check the pressure with a good tire-pressure gauge.
3. Compare reading with sprayer-pressure gauge.
4. Inflate the tire to several other pressures and compare readings.

Method II

In emergencies, output from a *new* stainless-steel nozzle tip for a measured time (1 min or longer) can also be used (see Tables 5 and 6 for the output from various sized nozzle tips). The measured output should equal that shown for the tip at the pressure indicated. If not, the pressure gauge is in error but can be operated if the reading on the gauge is changed to provide the correct flow from the nozzle tip.

Fig. 22 Pressure relief valve.

Fig. 23 Unloader valve.

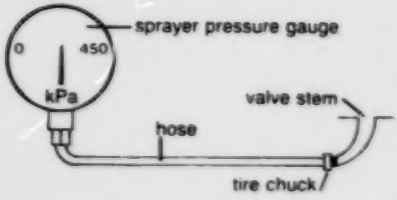

Fig. 25 Checking spray pressure.

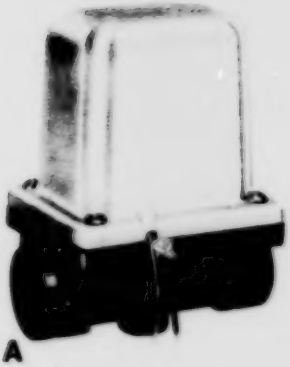

Fig. 24 Electronic regulating valve and remote control: (*A*) electronic regulating valve, (*B*) remote control for regulating valve.

Most sprayers have the gauge located on the selector valve. To check for pressure drops in the supply lines, mount a second gauge temporarily on the end of the boom and compare readings with those from the gauge on the selector valve. Readings from the two gauges should be close (within 15 kPa) but not necessarily identical as there may be a pressure drop, depending on plumbing size and line length. Increase the reading at the selector valve gauge by the difference measured to ensure correct pressure at the nozzles. Several sprayer manufacturers have the gauge connected so that it reads actual boom pressure. This situation is most desirable and may be accomplished by running a small-diameter (3-mm) flexible line from a boom mid point to the control location. This tube also acts as a pressure gauge damper if filled with air.

SCREENS AND FILTERS

Use metal screens of 80 or 100 mesh size (mesh size refers to the number of wires per linear 25 mm) in the tank filler opening (Fig. 26), to effectively prescreen both water and pesticide before they enter the tank. Wettable powders require a 40- or 50-mesh filter.

Add extra filtration if necessary to help prevent the nozzles from plugging and to prevent foreign material from entering the pump. A filter (Fig. 27) is required between the tank and the pump when using roller, piston, diaphragm, and turbine pumps. As centrifugal pumps can handle foreign material without damage and have low suction capability, place the filter on the outlet side of the centrifugal pump.

Avoid using felt filters. They do not filter adequately, deteriorate with use, and result in nozzles becoming plugged. They clog easily, especially with wettable powders. They have high flow restrictions as compared with metal screen filters. Screen filters provide greater filtering area, are easy to clean, and can be used with wettable powders.

BOOMS AND SUPPORTS

The boom tubing may be made of aluminum because of its light weight, although galvanized steel tubing is commonly used because of its higher strength. PVC material is also used and is resistant to most pesticides but requires additional support.

The boom support must provide stability and maintain a preset boom height. Supports may be a single member or of truss-like construction to prevent flexing of the boom or for carrying dry-boom installation. Vertical or horizontal whipping of the boom and boom bounce cause uneven application; therefore, the booms must be well supported. Fixed boom tandem wheels provide a smoother ride for the boom than single, castering wheels; however, the wheels may damage the crops on sharp turns. Spring suspensions on boom wheels with

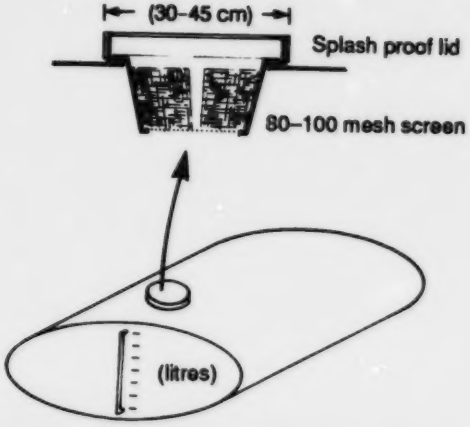

Fig. 26 Sprayer tank with screen in opening.

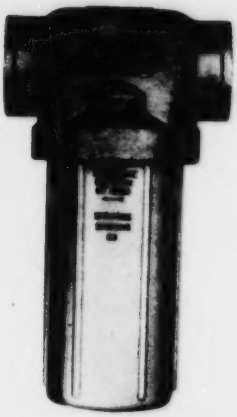

Fig. 27 In-line filter.

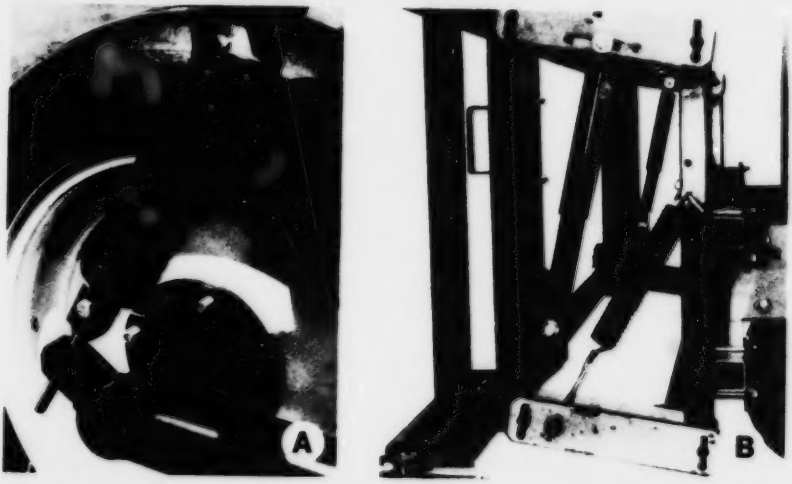

Fig. 28 Suspension systems: (*A*) shock-mounted boom support wheel, (*B*) suspension boom system.

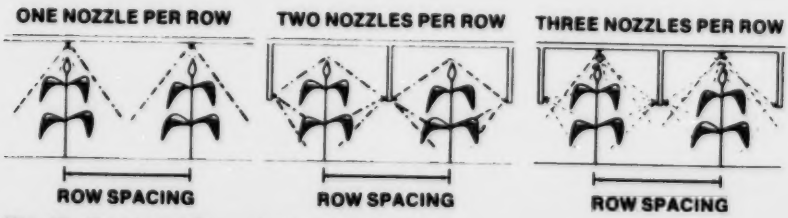

Fig. 29 Nozzle configuration for row spraying.

shock absorbers (Fig. 28*A*) provide a smooth boom ride on some sprayers. A good suspension boom system (Fig. 28*B*) with automatic leveling and damping also provides reasonable boom height control.

The boom support must also provide for fast, simple adjustments of nozzle height and angle. A single, parallel linkage adjustment to provide a height range of 20–75 cm above the ground is preferable. The adjustment of the nozzle angle should range from horizontally rearward to 45° forward. Spray should not interfere with any support component throughout the adjustment range. Row-crop sprayers must provide means to attach nozzles and drop tubes to match row spacing and plant heights. Examples of some configurations are shown in Fig. 29.

SHUT-OFF AND CONTROL VALVES

Efficient operation of the sprayer requires a separate control valve to each boom section (Figs. 30–34). Electronic solenoid valves (Fig. 31) are useful either for sprayers equipped with a cab or for sprayers towed by a tractor equipped with a cab. All components containing pesticides must remain outside the cab to isolate the operator and to avoid any drenching with pesticide, should a hose failure occur.

Globe valves (Fig. 32) may be used for throttling, such as on the agitation line. For other applications, gate or ball valves (Figs. 33 and 34) are preferred because of their low flow restriction when fully open.

PLUMBING

Undersized hoses and fittings can severely reduce the capacity or flow of any pump. Table 2 lists the minimum sizes of pumps, lines, fittings, and other components according to sprayer size, application rate, and speeds.

Hose material should resist pesticide action and withstand pressures up to 1400 kPa for low-pressure sprayers; higher-quality hose (2:1 safety factor) is required for high-pressure sprayers. Pump inlet hoses must resist collapse resulting from suction.

SPRAYER PLUMBING CIRCUITS

Figs. 35–38 illustrate the proper plumbing circuits for various types of sprayer pumps.

PESTICIDE METERING

Pesticide metering is accomplished by two methods. Pesticide injection systems meter only the pesticide, usually by controlling a pumping system. Metering of the pesticide mixture from a conventional sprayer is determined by the nozzle tips and operating pressures.

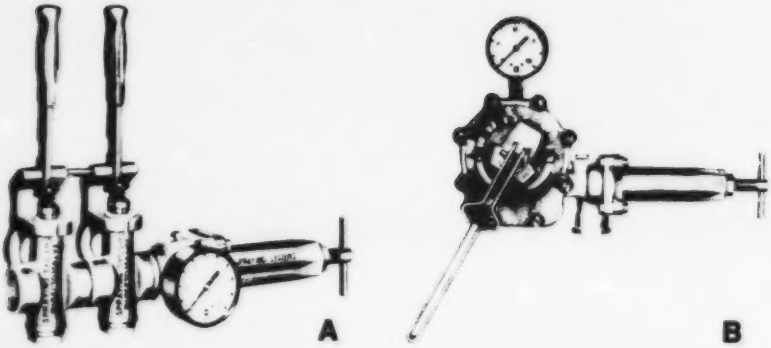

Fig. 30 Manually controlled boom valves.

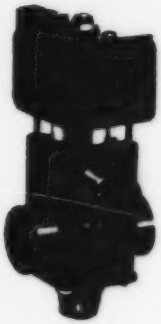

Fig. 31 Electronic solenoid valve.

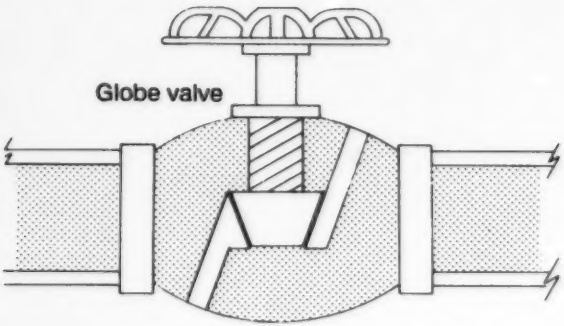

Fig. 32 Globe valve.

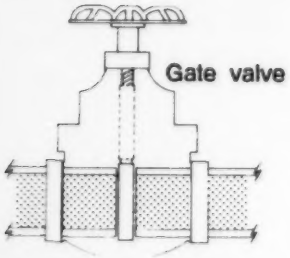

Fig. 33 Gate valve.

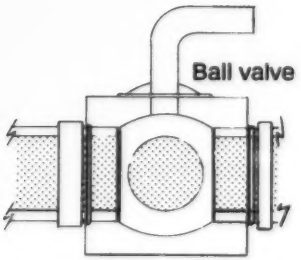

Fig. 34 Ball valve.

Table 2 Pump and plumbing sizes for an application volume of 100 L/ha

Sprayer		Pump size for travel speeds (km/h)				Plumbing sizes (I.D. mm)*						
						Pump hose		Boom				
Boom width (m)	Tank size (L)	6	8	10 (L/min)	12	In	Out	Line	Pipe	Bypass line	Agitator line	Filter ports
10	680	25	29	34	38	20	20	13	20	13	13	20–25
	900	29	32	38	42	25	20	13	13–20	13	13	20–25
12	900	32	36	42	47	25	20	13–20	20–25	13	13	25
	1130	36	40	46	52	25	20	13–20	20–25	13	13	25
	1350	40	45	50	56	25	20	20	20–25	13	13–20	25
15	1130	40	47	53	59	25	20	13–20	20–25	20–25	13	25
	1350	44	51	57	63	25	20–25	13–20	20–25	13–20	13	25
	1800	52	58	65	72	25–32	20–25	13–20	20–25	13–20	20	25
18	1350	48	56	63	71	25–32	20–25	13–20	25–32	13–20	20	25
	1800	56	64	72	79	25–32	20–25	13–20	25–32	20–25	20	25
	2270	64	72	80	88	25–32	25	20	25–32	20–25	20	25
24	1850	64	74	85	95	25–32	25	20	25–32	20–25	20	25–32
	2270	72	83	93	104	25–32	25	20	25–32	20–25	20	25–32
30	2270	70	94	118	140	32–40	32	25	32–40	20–25	25	32
	3600	86	115	144	173	32–40	32–40	25	32–40	25–32	25	32–40

* Where two sizes are given, the smaller size refers to the slowest travel speed and the larger size to the fastest travel speed.

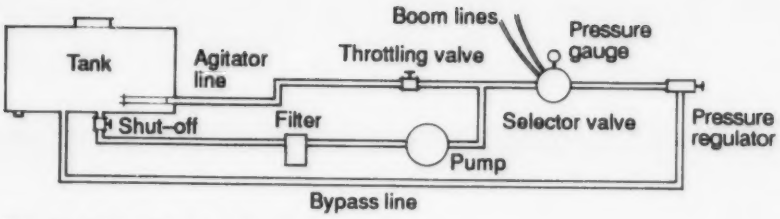

Fig. 35 Schematic of roller pump hook-up.

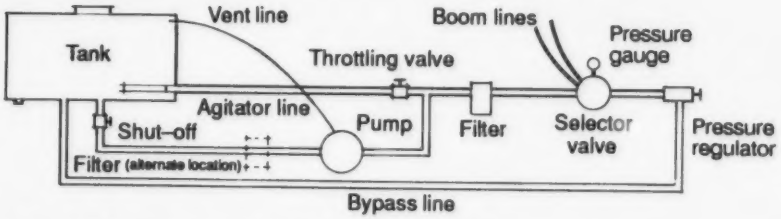

Fig. 36 Schematic of centrifugal pump hook-up with pressure regulator.

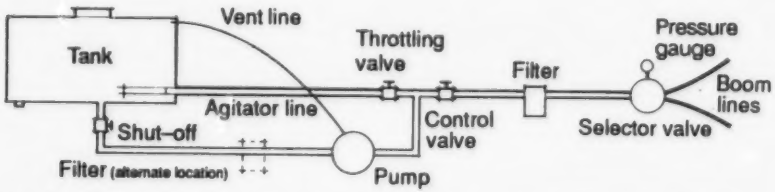

Fig. 37 Schematic of centrifugal pump hook-up without pressure regulator.

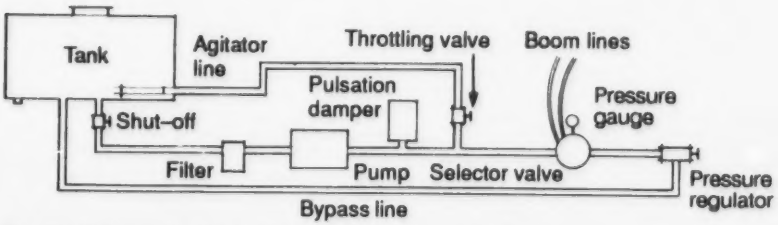

Fig. 38 Schematic of piston or diaphragm pump hook-up.

PESTICIDE INJECTION SYSTEMS FOR SPRAYING

Instead of mixing the pesticide and water in one tank, a pesticide injection system may be used. These systems (Figs. 39*A*, *B*) have much merit if properly designed with adequate controls and monitoring. Separate tanks for one or more pesticides and for the water supply have provision to prevent pesticide from entering the water supply tank.

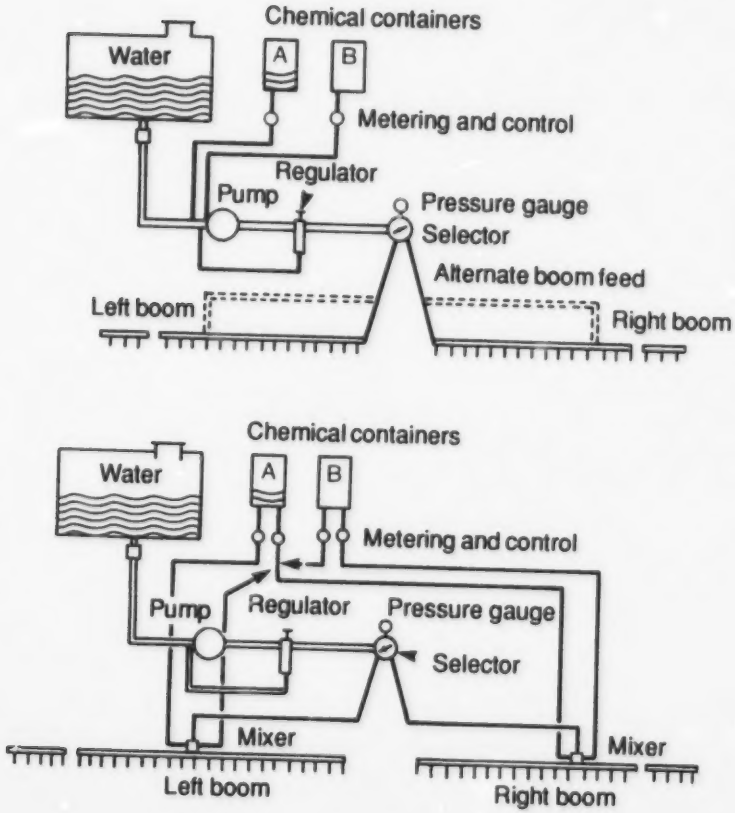

Fig. 39 Schematic of pesticide injection systems: (*A*) injection at pump, (*B*) injection at boom.

An adequate injection system should perform the following functions:

- meter all pesticides at rates ranging from <0.1 L/min to >3.5 L/min (depends upon pesticide, sprayer width, and travel speed)
- meter pesticide accurately, unaffected by viscosity or composition
- maintain pesticide application rate as travel speed changes
- maintain pesticide application rate as a boom section is turned off or on
- allow easy adjustment, calibration, and monitoring of pesticide flow rate
- provide quick response time for spot spraying with a second pesticide*
- mix pesticide uniformly with the water
- have provision to empty and thoroughly clean the injection system.

Advantages of injection systems for spraying are as follows:

- premixing of pesticide and water is avoided
- spot-spraying with a second pesticide is possible*
- unused pesticide can be retrieved still in undiluted form
- shutdown due to bad weather does not waste pesticide
- conditions are safer for the applicator
- pesticide costs may be reduced.

Pesticide injection systems added to conventional sprayers usually require major changes to wet-boom pipe assemblies to reduce response time for spot applications. Response time is the time for the last nozzle on the boom to emit pesticide. Current sprayers, 24 m wide and equipped with injection systems, may have a total response time in excess of 1.5 min, depending on the rate at which water is applied. A sprayer with a 1-min response time and traveling at a speed of 8 km/h will result in a travel distance of 134 m before the last nozzle on each boom emits the pesticide. Injection at the boom (Fig. 39*B*) reduces the response time.

NOZZLE TIPS

Materials

Nozzle tips are manufactured from many different types of material. The materials most commonly used are stainless steel, nylon, and brass. Hardened stainless steel and ceramic tips are used where extra long life is desired or very abrasive pesticides are applied. Other materials used are acetal copolymer (Kematal) and mineral-based ceramic (Korundum). Both Kematal and Korundum have excellent resistance to wear, whereas brass tips wear rapidly.

* *CAUTION*: Apply together only pesticides recommended for tank-mix application. Serious and damaging results to the crop, equipment, and personnel may result if label recommendations are not followed.

In an accelerated wear test using powdered quartz in water to increase the wear rate, Alumex and Kematal tips showed insignificant wear after 25 h. The other materials had the following relative wear rates:

ceramic	1
nylon	2
stainless steel	4
brass	24

Nozzle tips may be easily damaged when being cleaned. Even a toothpick can damage the softer materials such as aluminum, brass, nylon, and Kematal. In a test with a weight of only 500 g applied to a toothpick inserted into the orifice, both nylon and Kematal orifices were seriously damaged. The outputs were not changed but the distribution pattern showed heavy streaks, which showed that the tips were ruined. If any of the softer materials are used, carry extra tips on the sprayer so that blocked tips need not be cleaned in the field. Clean these nozzle tips only with compressed air and never by inserting a foreign object into the orifice.

Types

There are five main types of nozzle tips: flat spray tips, even flat spray tips, flooding tips, cone tips, and off-centre tips.

Flat spray tips

Flat spray tips are the type most suitable for broadcast pesticide spraying. They are available in a wide range of orifice sizes, materials, and spray angles. The patterns are tapered at the edges to produce a uniform overall pattern with some overlap between adjacent patterns. The pattern varies with height, pressure, and tip manufacturer, so the correct combination of nozzle tip height, pressure, and spacing is needed to obtain a uniform pattern along the boom (Fig. 40, Table 3).

Flat spray tips are usually positioned so that the spray is emitted straight down. In some cases, however, a pesticide manufacturer may recommend that the tips be oriented 45° forward. When tips are pointed 45° forward, the boom height should be 75% of the heights shown in Table 3. Consult the pesticide label or a company representative for information regarding the best tip orientation to use with specific pesticides.

Flat spray tips are available with many different spray angles but the 80° and 110° angle tips are the most commonly used for broadcast spraying. Tips with 65° spray angle have been used in the past but are not recommended because of the extra operating height needed. Increased height increases the potential for spray drift.

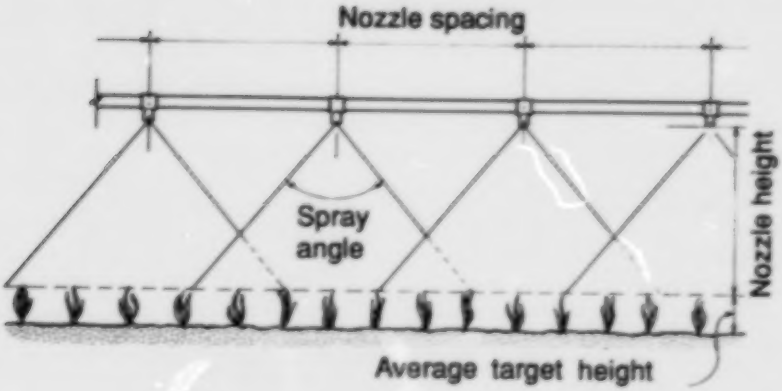

Fig. 40 Measuring nozzle tip height.

Table 3 Recommended pressures and heights for standard and extended range tips

Tip type	Pressure range (kPa)	Recommended height above target*	
		50-cm spacing (cm)	75-cm spacing (cm)
80° standard	200–300	45–50	not recommended**
110° standard	200–300	35–45	35–40 or 60
80° extended range	100–300	40–45	not recommended**
110° extended range	100–300	25 or 45	40 or 60

* These are normally the best heights for these categories of tips but there are significant variations for certain imported brands. Contact your provincial agricultural engineer for individual recommendations.

** May be satisfactory for high-volume tips.

Small sizes of flat spray tips may produce unacceptable patterns and drift potentials at all heights and pressures (outputs <0.3 L/min at 300 kPa). Contact your provincial agricultural engineer for advice before purchasing any tips in the smaller sizes. Special tip designs, such as a twin tip, are also available for specific applications, such as for fungicides.

Determine the required output of a spray tip for broadcast spraying from the following formula:

$$\text{tip output (L/min)} = \frac{\text{application volume (L/ha)} \times \text{speed (km/h)} \times \text{nozzle spacing (cm)}}{60\,000}$$

Example: desired application volume 100 L/ha
desired forward speed 8 km/h
nozzle spacing 50 cm

$$\text{tip output} = \frac{100 \times 8 \times 50}{60\,000} = 0.667 \text{ L/min}$$

Refer to a nozzle manufacturer's catalog to select the correct size of tip. The desired output must be obtained at the recommended pressure for that tip.

Variable-pressure spray tips, commonly referred to as low-pressure (LP) or extended-range (XR or LFR) tips, produce acceptable patterns at pressures as low as 100 kPa. Tips designated as LP may have higher output than those designated as XR at equivalent pressures. They can also be operated at pressures as high as 300 kPa if desired and are available with 80° and 110° spray angle.

For best operation, offset flat spray tips a few degrees of parallel to the boom. New, quick-attach, nozzle tip holders automatically offset the nozzle tips a few degrees. The outputs in Tables 4 and 5 are all obtained using water.

Even flat spray tips

Even flat spray tips are used for band spraying (Fig. 41). They are normally identified with an E in their identification code (e.g., 4002E, LE2-80, or E02-F110). They are available with 40°, 80°, 95°, and 110° spray angles. The edges of the patterns are not tapered as they are with regular flat spray tips and the patterns are not overlapped (Tables 6 and 7).

Flooding tips

Flooding tips are designed to apply liquid fertilizers and other chemicals not requiring precision application (Table 8). The spray deposit is much heavier at the edges of the pattern if partially overlapped, resulting in streaking. Operate flooding tips with either no pattern overlap or 100% pattern overlap. The round orifices on flooding tips are less likely to plug than the elliptical orifices found on other flat spray tips, but the patterns produced by flooding tips vary

Table 4 Application volumes—flat spray tips*

Tip manufacturer					Application volume at 50-cm spacing and various ground speeds (km/h)				
Delavan	Lurmark	Spraying Systems	Pressure (kPa)**	Tip output (L/min)	6	8	10 (L/ha)	12	18
LF1-80°	01-F80	8001	100	0.22	47	35	27	23	16
		XR8001†	150	0.28	56	42	33	28	19
			200	0.32	64	48	39	32	21
			250	0.36	72	54	43	36	24
			275	0.38	76	57	45	38	25
			300	0.39	79	59	47	39	26
LF1.5-80°	015-F80	80015	100	0.34	70	53	42	35	23
		XR80015†	150	0.42	84	63	50	42	28
			200	0.48	97	73	58	48	32
			250	0.54	108	81	65	54	36
			275	0.57	113	85	68	57	38
			300	0.59	118	89	71	59	39
LF2-80°	02-F80	8002	100	0.45	93	70	56	47	31
LFR2-80°†		XR8002†	150	0.56	112	84	67	56	37
			200	0.65	129	97	77	64	43
			250	0.72	144	108	86	72	48
			275	0.76	151	113	90	76	51
			300	0.79	158	118	95	79	53

(continued)

Table 4 Application volumes—flat spray tips* (*continued*)

Tip manufacturer					Application volume at 50-cm spacing and various ground speeds (km/h)				
Delavan	Lurmark	Spraying Systems	Pressure (kPa)**	Tip output (L/min)	6	8	10 (L/ha)	12	18
LF3-80°	03-F80	8003	100	0.68	139	105	83	70	47
LFR3-80°†		XR8003†	150	0.84	167	126	100	84	56
			200	0.97	193	145	116	97	64
			250	1.08	220	162	130	108	72
			275	1.13	230	170	136	113	75
			300	1.18	237	178	142	118	79
LF4-80°	04-F80	8004	100	0.91	183	139	112	93	62
LFR4-80°†		XR8004†	150	1.12	220	167	134	112	74
			200	1.29	260	193	155	129	86
			250	1.44	290	220	173	144	96
			275	1.51	305	230	181	151	101
			300	1.58	316	237	189	158	105
LF5-80°	05-F80	8005	100	1.17	233	175	139	117	78
LFR5-80°†		XR8005†	150	1.40	280	210	167	140	93
			200	1.61	320	240	193	161	107
			250	1.80	360	270	216	180	120
			275	1.88	378	283	227	189	126
			300	1.97	395	296	237	197	132

(*continued*)

Table 4 Application volumes—flat spray tips* (*concluded*)

Tip manufacturer					Application volume at 50-cm spacing and various ground speeds (km/h)				
Delavan	Lurmark	Spraying Systems	Pressure (kPa)**	Tip output (L/min)	6	8	10	12	18
					(L/ha)				
LF6-80°	06-F80	8006	100	1.40	275	208	139	120	93
LFR6-80°†		XR8006†	150	1.68	330	250	167	144	112
			200	1.93	390	290	230	166	129
			250	2.16	432	324	259	216	144
			275	2.27	453	340	272	227	151
			300	2.37	474	355	284	237	158

Note: The application volumes are the same for the 110° tips where available.

* Tables of application volumes are also available for other makes, nozzle tip sizes, spacings, and forward speeds. Slight variations occur between tips from different manufacturers and even between tips from the same manufacturer. Therefore, it is important to calibrate sprayers.

** Extended range tips may be operated at low pressures down to 100 kPa, whereas standard or regular tips do not give satisfactory spray patterns at pressures below 200 kPa.

† Extended range tips.

Table 5 Application volumes—low-pressure (LP) flat spray tips*

Tip manufacturer				Application volume at 50-cm spacing and various ground speeds (km/h)				
Lurmark	Spraying Systems	Pressure (kPa)	Tip output (L/min)	6	8	10 (L/ha)	12	18
LP01-80	8001LP	100	0.37	74	56	45	37	25
LP01-110	11001LP	150	0.46	91	68	55	46	30
		200	0.53	105	79	63	53	35
		250	0.59	118	88	71	59	39
		275	0.61	123	93	75	61	47
LP015-80	80015LP	100	0.56	112	84	67	56	37
LP015-110	110015LP	150	0.68	137	102	82	68	46
		200	0.79	158	118	95	79	53
		250	0.88	176	132	106	88	59
		275	0.93	186	139	111	93	61
LP02-80	8002LP	100	0.74	149	112	89	74	50
LP02-110	11002LP	150	0.91	182	137	109	91	61
		200	1.05	210	158	126	105	70
		250	1.18	240	177	141	118	78
		275	1.23	247	186	148	123	83
LP03-80	8003LP	100	1.12	220	167	134	112	74
LP03-110	11003LP	150	1.37	270	210	164	137	91
		200	1.58	320	240	189	158	105

(*continued*)

Table 5 Application volumes—low-pressure (LP) flat spray tips* (*concluded*)

Tip manufacturer		Pressure (kPa)	Tip output (L/min)	Application volume at 50-cm spacing and various ground speeds (km/h)				
Lurmark	Spraying Systems			6	8	10 (L/ha)	12	18
		250	1.77	350	260	210	176	118
		275	1.86	365	277	222	186	123
LP04-80	8004LP	100	1.49	300	220	179	149	99
LP04-110	11004LP	150	1.82	360	270	220	182	122
		200	2.11	420	320	250	210	140
		250	2.35	470	350	280	240	157
		275	2.47	498	365	297	247	164
LP05-80	8005LP	100	1.86	370	280	220	186	124
LP05-110	11005LP	150	2.28	460	340	270	230	152
		200	2.63	530	390	320	260	175
		250	2.94	590	440	350	290	196
		275	3.08	614	465	365	309	206
LP06-80	8006LP	100	2.23	450	330	270	220	149
LPO6-110	11006LP	150	2.74	550	410	330	270	182
		200	3.16	630	470	380	320	210
		250	3.53	710	530	420	350	240
		275	3.70	747	548	448	365	247

* Tables of application volumes are also available for other tip sizes, spacings, and forward speeds.

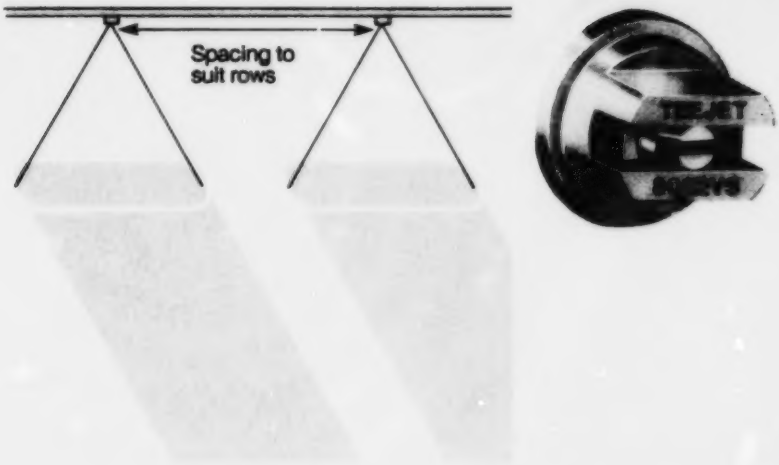

Fig. 41 Even spray tip and tip spacing.

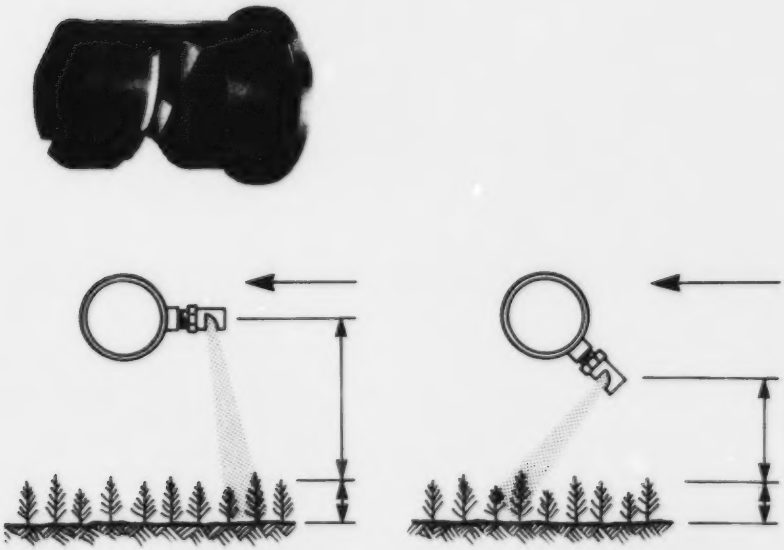

Fig. 42 Flooding nozzle tip and its spray orientations.

Table 6 Tip heights for various band widths*

Band width (cm)	Tip height at various spray angles (cm)			
	40°	80°	95°	110°
20	27	12	9	7
25	34	15	12	9
30	41	18	14	11
35	48	21	16	13

* To select the correct size of even flat spray tip, use the formula given for the flat tips under "Flat spray tips." Substitute band width for nozzle spacing.

greatly with pressure, material being sprayed, and tip size. It is therefore not possible to make any general recommendations regarding best heights, pressures, or spacings, except that spacings should not exceed 1.5 m and pressures should normally be between 150 and 300 kPa. The mounting angle of flooding tips can be varied to obtain different directions of delivery (Fig. 42). A straight-down delivery produces the least potential for spray drift but the worst pattern, whereas a horizontal delivery produces a better pattern but more potential for spray drift. Because of their generally uneven patterns, use flooding tips for applying pesticides only when specifically recommended by the pesticide manufacturer.

Cone tips

Hollow cone and solid cone tips are used primarily for spraying insecticides and fungicides in row crops. Hollow cones are used when low-volume applications of fine droplets are needed for thorough coverage, whereas solid cones are best suited for high-volume applications where dense foliage requires a penetrating spray. These nozzles are best operated at high pressures ($\geq$550 kPa) and are often used in drop tube configurations (Fig. 29). They wear well when using wettable powders and other abrasive pesticides. Because the nozzles do not produce a uniform spray pattern (Fig. 43), they are not used in broadcast herbicide applications. Some nozzle types, such as Raindrop (Delavan) (Table 9) and Whirl Jet (Spraying Systems), produce larger droplets that are more resistant to drift.

Table 7 Outputs for even flat spray tips

Tip no.*	Pressure (kPa)	Tip output (L/min)
1	150	0.28
	200	0.32
	250	0.36
	275	0.38
1.5	150	0.42
	200	0.48
	250	0.54
	275	0.57
2	150	0.56
	200	0.65
	250	0.72
	275	0.76
3	150	0.84
	200	0.97
	250	1.08
	275	1.13
4	150	1.12
	200	1.29
	250	1.44
	275	1.51
5	150	1.40
	200	1.61
	250	1.80
	275	1.89
6	150	1.68
	200	1.93
	250	2.16
	275	2.27

* Tip no. refers to the size designation. For example No. 1 is a Delavan LE1; Teejet 4001E, 8001E, or 9501E; or Lurmark E01-F80 or E01-F110.

Off-centre tips

Off-centre tips are used primarily for spraying areas that are inaccessible to a spray boom, such as fence rows and road ditches. As the name suggests, the spray pattern is directed off to one side of the nozzle tip instead of symmetrically to both sides. Depending on the orifice size and discharge height they can spray a width of 2–5 m to one side of the nozzle. Because of the horizontal direction of the spray output they have a higher potential for spray drift than nozzles that direct the spray down. They may be used on a boom-end of a field

Table 8 Application volumes—flooding tips

Tip manufacturer			Tip output (L/min)	Application volume at 100-cm spacing, 250 kPa pressure, and various ground speeds (km/h)			
Delavan	Lurmark	Spraying Systems		6	8	10	18
				(L/ha)			
D 1	AN 1	TK 1	0.72	72	54	43	24
D 1.5	AN 1.5	TK 1.5	1.08	108	81	65	36
D 2	AN 2	TK 2	1.44	144	108	86	48
D 2.5	AN 2.5	TK 2.5	1.80	180	135	108	60
D 3	AN 3	TK 3	2.16	216	162	130	72
D 4	AN 4	TK 4	2.88	288	220	173	96
D 5	AN 5	TK 5	3.60	360	270	220	120
D 7.5	AN 7.5	TK 7.5	5.40	540	410	320	180

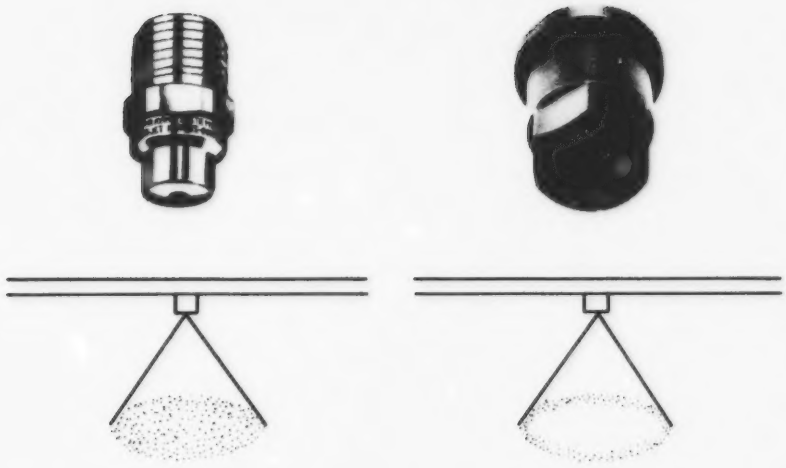

Fig. 43 Cone tips and their spray deposit patterns.

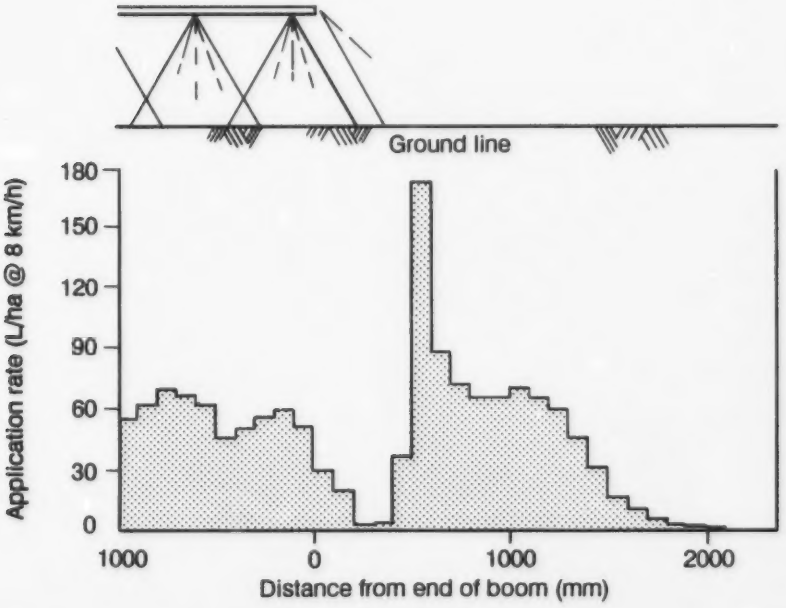

Fig. 44 Flat spray and off-centre spray tip distribution patterns.

Table 9 Application volumes of Raindrop® nozzle

Nozzles			Application volume at 50-cm and 100-cm spacing and various ground speeds (km/h)					
			50-cm spacing			100-cm spacing		
No.	Pressure (kPa)	Tip output (L/min)	6	8	10	6	8	10
			(L/ha)					
RA 2	200	.64	128	96	77	64	48	38
	275	.76	151	114	91	75	57	46
RA 4	200	1.29	257	193	156	128	96	78
	275	1.51	301	227	180	151	114	90
RA 5	200	1.61	321	242	193	161	121	96
	275	1.89	378	284	227	189	142	114
RA 6	200	1.93	388	289	232	194	144	116
	275	2.27	452	341	272	226	170	136
RA 8	200	2.58	516	388	309	258	194	154
	275	3.02	605	452	363	303	226	182

(continued)

Table 9 Application volumes of Raindrop* nozzle (*concluded*)

Nozzles			Application volume at 50-cm and 100-cm spacing and various ground speeds (km/h)					
			50-cm spacing			100-cm spacing		
No.	Pressure (kPa)	Tip output (L/min)	6	8	10	6	8	10
			(L/ha)					
RA 10	200	3.22	645	482	388	322	241	194
	275	3.78	756	566	452	378	283	226
RA 15	200	4.84	981	734	588	490	367	294
	275	5.67	1139	855	684	569	427	342
RA 20	200	6.45	–	–	–	642	482	385
	275	7.56	–	–	–	753	566	452
RA 25	200	8.06	–	–	–	803	603	482
	275	9.45	–	–	–	946	709	568

* Manufactured by Delavan.

sprayer but only for spraying ditches and fence rows. As they generally produce very uneven patterns (Fig. 44) they should be shut off for regular field spraying. Off-centre nozzles are also used on boomless sprayers for brush and weed control on roadsides and for reaching otherwise inaccessible areas. They may be mounted in pairs or in clusters with other nozzle types to increase the width of coverage from a central location. Off-centre nozzles are available in many sizes with outputs ranging from <1 L/min to >100 L/min. They may be identified either with an "OC" and the nozzle number, such as OC02 or OC10 (Teejet and Lurmark), or with an "LX" (Delavan) (Table 10).

The width of coverage varies from 2 m with the No. 2 tip and a 60-cm spraying height, to about 7 m with a No. 20 tip and a 90-cm height. Larger capacity off-centre tips are also available.

Table 10 Outputs for off-centre tips

Tip number	Pressure (kPa)	Tip outputs (L/min)
OC02, LX2	200	0.65
	300	0.79
OC03, LX3	200	0.97
	300	1.18
OC04, LX4	200	1.29
	300	1.58
OC06, LX6	200	1.93
	300	2.37
OC08, LX8	200	2.58
	300	3.16
OC10	200	3.22
	300	3.95
OC12, LX12	200	3.87
	300	4.74
OC16, LX16	200	5.16
	300	6.32
OC20	200	6.45
	300	7.90

Quick-change holders

Most nozzle manufacturers now produce nozzle bodies and caps that allow tips to be changed quickly and easily without the use of wrenches or other tools, which reduces the time required to change tips and the possibility of losing tips or screens. The caps and tips are available in various colors so that nozzles of the same size can be readily identified (Table 11), which helps to eliminate mixups, although different manufacturers do not use the same color coding. Another feature of most of the quick-change holders is that they provide automatic tip alignment.

Quick-change nozzle assemblies are available with or without diaphragm check valves. They are also available with multiple heads to make changing application volumes even more convenient.

Table 11 Color-coding guide for tips

	Nominal tip size			
Manufacturer	01	015	02	03
Spraying Systems	orange	green	yellow	blue
Delavan	–	brown	gray	orange
Lurmark	pink	light brown	orange	red
Albuz	–	yellow	–	–

Nozzle strainers and screens

Nozzle strainers and screens (Fig. 45A) are used to prevent foreign particles from entering tip orifices. Slotted strainers are typically used when spraying liquids containing suspended solids, and with disc-cone tips. They are available with various slot sizes ranging from 16 to 50 mesh equivalent. Slotted strainers are made of brass, nylon, or aluminum.

Nozzle screens are used with the smaller sizes of flat spray tips, and various solid and hollow cone tips. Screens are typically available in 24-, 50-, 80-, 100-, and 200-mesh sizes. The screens are made of stainless steel and the strainer body is made of brass, polypropylene, nylon, aluminum, or stainless steel. Tips with outputs of 0.2–0.6 L/min typically use 100-mesh screens, those with outputs of 0.6–3.0 L/min use 50-mesh screens, and those above 3.0 L/min require no screens. Nozzle screens are available in two basic configurations—cylindrical and cup-shaped. The cylindrical-type strainers are preferred because they are larger and do not plug as readily.

Nozzle check valves

Nozzle check valves prevent pesticides from leaking out of the spray booms when the flow of liquid is shut off, which prevents the loss of pesticide. Nozzle check valves also allow rapid rise of pressure in the booms when the liquid flow is turned on, thus preventing untreated areas or spots.

Ball check valves

Ball check valves are available as separate units but are usually incorporated into nozzle strainers (Fig. 45*A*). Various valve-opening pressures can be provided by selecting different springs. The most common pressure is 35 kPa, but 70, 140, and 280 kPa check valves are also available.

When using ball check valves, increase the boom pressure by an amount equal to the valve-opening pressure to maintain the desired pressure at the nozzle tip. For example, if the desired nozzle pressure is 250 kPa and the ball check valves are equipped with 35-kPa springs, set the boom pressure at 285 kPa.

It is important to select a ball check valve that is suitable for the tip flow rate desired. Higher flow rates cause greater pressure drops. If the tip flow rate is near the top end of the recommended range, the pressure drop may be somewhat greater than the rated values.

Proper maintenance of ball check valves is important. Occasional flushing of the booms with a detergent solution will help to prevent the balls from sticking and also will reduce leakage caused by foreign material lodged between the seat and the ball.

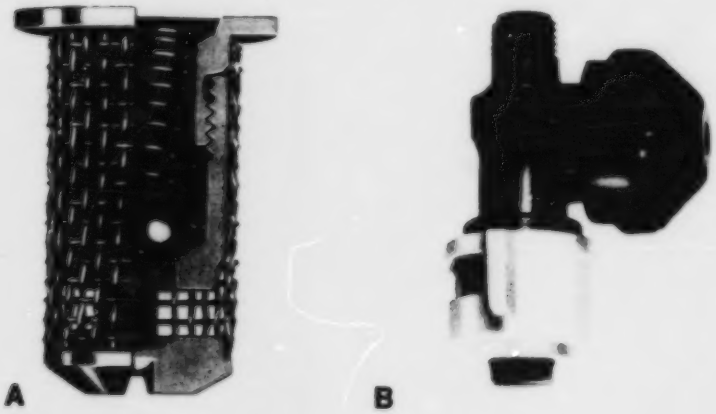

Fig. 45 Check valves and strainer: (*A*) ball check valve and strainer, (*B*) diaphragm check valve.

Diaphragm check valves

Diaphragm check valves (Fig. 45*B*) have several advantages over ball check valves. They are less prone to sticking and erratic behavior and have no measurable pressure drop when operated within their recommended flow rates. They are, however, more expensive than ball check valves.

The commonly available diaphragm check valves show little pressure drop at flow rates below 3 L/min. Large models have little pressure drop for flows up to 7 L/min. Valve opening pressures are typically 50–60 kPa, but once the valve is opened there is no measurable pressure loss. Therefore, do not increase boom pressure as is the case when using ball check valves.

Miscellaneous check valves

One type of check valve uses a flat rubber band to shut off the flow below a certain pressure. It operates in a similar manner to the ball check valves, i.e., there is a continuing pressure drop after opening and the boom pressure must therefore be increased to maintain the desired nozzle pressure.

Replacement

Replace a nozzle tip if it shows any visible streaking or distortion, if the output varies more than 5% from the average, or if the output is more than 15% greater than its original output. To check a set of tips, follow this procedure:

1. Look for any streaking or distortion of the pattern; if cleaning the tip doesn't solve the problem, replace the tip.
2. Collect the output of each individual tip for a fixed time (1 min) at a fixed pressure. Compare the outputs with the original rated output and replace any tips that are more than 15% higher than the original.
3. Calculate the average output of the tips and replace any that deviate more than 5% from the average.

Nozzle flowmeters

A fast and easy method of checking tip outputs is desirable to help determine when tips need to be replaced. A graduated cylinder and stop watch provide the most reliable results when properly used (Fig. 46*A*). Several companies have developed hand-held, instant-readout flowmeters for measuring individual tip outputs (Fig. 46*B*). These too should be checked periodically for accuracy.

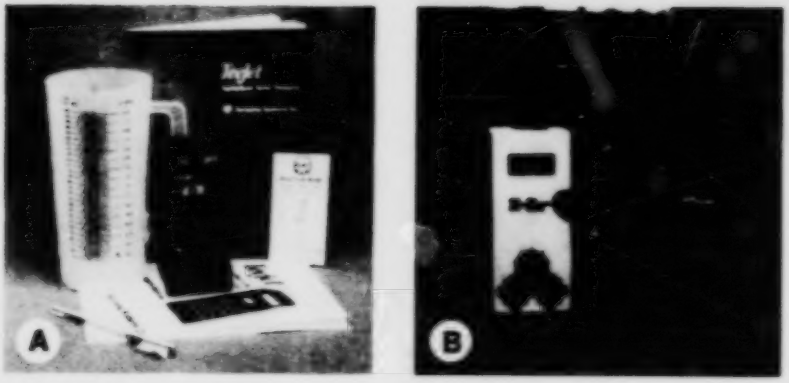

Fig. 46 Flow-measuring devices: (*A*) flow-measuring kit, (*B*) flowmeter.

SPRAY GUNS

Hand-held spray guns (Fig. 47) are used for spot spraying weed patches in fields, fence rows, roadsides, trees, and brush, as well as for spraying livestock and cleaning buildings and equipment. They are available with or without trigger controls. Standard and high-pressure models are available for use with pressures up to 7000 kPa. They normally operate with orifice discs made of hardened stainless steel. The output of the spray gun can be adjusted from a straight stream to a wide-angle cone spray depending on the coverage and throw required. The maximum horizontal throw with a straight-stream spray is typically between 10 and 15 m depending on the size of the orifice disc and the liquid pressure. Outputs vary from 1 L/min to >100 L/min depending on the orifice disc and pressure used. Various flat spray tips may also be used with spray guns if desired, instead of using orifice discs.

Fig. 47 Spray gun.

SPRAYER OPERATION

PLANNING

Planning begins with the decision to apply a pesticide to control a pest or pests in a field. After the problem is identified, a particular pesticide is chosen on the basis of ability to control a pest or pests, cost, relative toxicity, and environmental concerns. Then decisions must be made as to the volume and rate of application of the pesticide.

Application volume Application volume is determined by the speed of travel, tip size, and spray pressure. Practical travel speed is affected by the type of equipment used and field conditions. Nozzle tip size must be selected to apply the required volume at the desired speed as shown earlier. Most postemergent herbicides are recommended to be applied in a minimum of 100 L of water per hectare.

Note: In *all* cases read the pesticide manufacturer's label to determine application volume of not only the pesticide carrier but also the carrier for each application.

Application rate The container label shows the recommended amount of pesticide to apply in litres or kilograms per hectare.

The following guide is provided to assist in planning an entire spraying operation.

Application and calibration guide

A. Field location: _____

B. Field size (acres × 0.405): _____ ha

C. Crop: _____ Variety: _____

D. Pest(s) to control: _____

E. Pesticide(s) used: _____

F. Pesticide rate: _____ L/ha or _____ kg/ha

G. Spray volume required: _____ L/ha

H. Total pesticide required (multiply B × F): _____

I. Sprayer tank size (Imp. gal. × 4.55; U.S. gal. × 3.79): _____ L

J. Sprayer output = $\dfrac{60\,000 \times \text{L/min (per nozzle)}}{\text{km/h} \times \text{nozzle spacing (cm)}}$ = L/ha

Spray pressure: _____ kPa
Nozzle tip size: _____
Nozzle output: _____ mL/min or (÷ 1000)
= _____ L/min, at _____ kPa
Travel speed: _____ km/h

K. One tankful will cover (divide I ÷ J) = _____ ha

L. Pesticide per tankful (multiply F × K) = _____ L or kg

M. Number of loads to cover field (divide B ÷ K) = _____

REGULATIONS

Most provinces have legislation to control and regulate pesticide use (Appendix). These acts, published variously as Pesticides Control Act, Pesticide Act, Agriculture Chemicals Act, The Clean Environment Act, and so on, cover pesticide use and registration within each province. Provincial guidelines on handling and transport of pesticides, disposal of pesticide containers, permits, and training requirements for pesticide use, and so on, are based on these acts. Operators of private or commercial sprayers should obtain a copy of these acts from their respective provinces for detailed information.

MEASUREMENTS FOR SPRAYING

The Pest Control Products Act of Canada requires pesticide labels to use SI (metric units). To simplify calculations, measure all field sizes in hectares (ha), speed in kilometres per hour (km/h), and volumes in litres (L). Remember that an area of 1 ha measures 100 m × 100 m and contains 10 000 m^2. Conversion factors, if needed, are on the inside of the back cover.

Conversions

Acres are converted to hectares by multiplying by 0.40. Fig. 48 expresses the area of a section of land in terms of hectares. A section contains about 259 ha and is about 1609 m (1 mile) by 1609 m (1 mile). Travel speed in kilometres per hour is obtained by multiplying miles per hour by 1.61. Volume in litres is obtained by multiplying imperial gallons by 4.55 or U.S. gallons by 3.79.

Product requirements

Pesticide rates are given as litres or kilograms of product (liquid or powder) per hectare. To determine the amount of product required, multiply the rate by total hectares to spray. Divide by container size to determine the number of containers needed.

SPRAYER CALIBRATION

Accurate calibration of spraying equipment is an important aspect of pesticide usage. An application of more than the recommended rate is wasteful and may damage the crop; applications of less than the recommended rate may be ineffective and therefore wasteful.

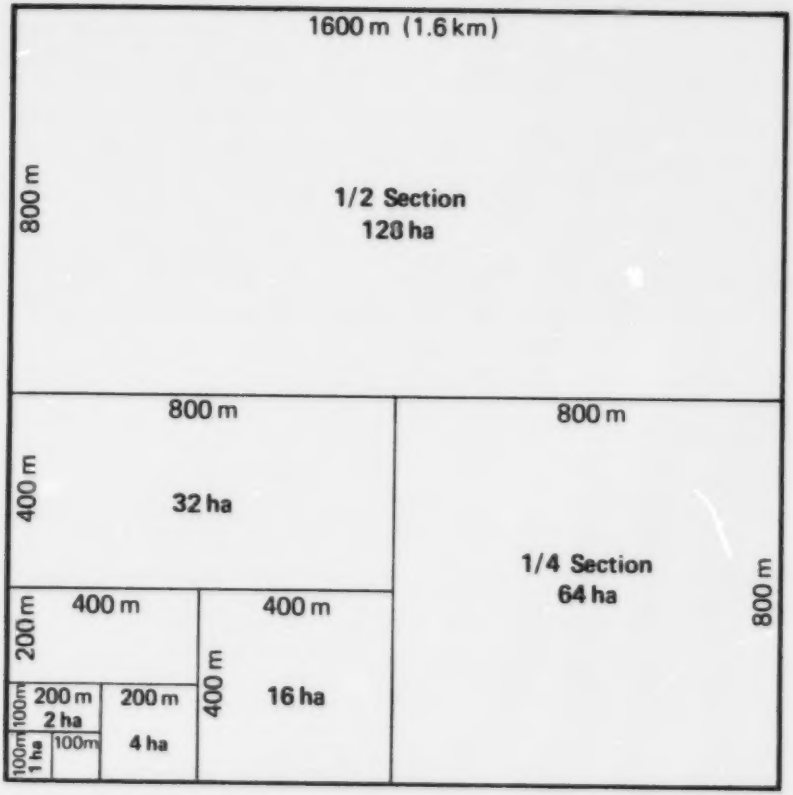

Fig. 48 Land divisions of a section using the metric system.

Nozzle calibration

To calibrate the nozzles, use the following procedures:

1. Check and clean all nozzles, screens, and filters.
2. Check pressure gauge for accuracy.
3. Check boom pressure with an accurate gauge and compare to sprayer gauge (should be within 15 kPa).
4. With sprayer operating at the desired spraying (boom) pressure, using water only, collect nozzle tip output for 1 min. If nozzle ball check valves are used, increase the pressure by the amount required to open the check valves.
5. Measure and record collected amount.
6. Repeat steps 4 and 5 for all tips.

7. Replace tips that have an output 5% greater than average or 15% higher than original or those that show streaks in the distribution pattern; clean and recheck nozzles with outputs of $<5\%$ of average (replace as necessary).

Recalibrate brass tips every 50 h and other tips every 200 h. The use of wettable powders requires more frequent recalibration of all tips. Calibrate all tips when installed on a sprayer, including the new tips.

Travel speed determination

To determine the travel speed, use the following procedures:

1. Select desired throttle setting (tachometer) and transmission gear. Throttle setting may depend on the type of sprayer pump used. For example, if pump is PTO-driven, the tractor may need to be operated at standard PTO speed (i.e., 540 or 1000 rpm). Transmission gear selection depends on field conditions (e.g., roughness or hills) and the desired workrate.
   Note: Unless the sprayer pump is ground-driven or an automatic rate controller is used, changes in travel speed change the application volume.
2. Run tests in the field to be sprayed with sprayer tank about half full of water; simulate actual field conditions as closely as possible.
3. Measure a 150-m course, preferably on level ground; mark the start and finish so that each is plainly visible from the tractor seat as you drive past.
4. Operate tractor at selected speed before start of marked course. When even with first marker, start the stop watch; stop the stopwatch when even with the finish marker. Repeat this test several times and average the times:

$$\text{average time (min)} = \frac{\text{sum of times}}{\text{no. of tests}}$$

$$\text{speed (km/h)} = \frac{\text{distance (m)}}{\text{average time (min)}} \times \frac{60}{1000}$$

or for a 150-m course:

$$\text{speed (km/h)} = \frac{9}{\text{average time (min)}}$$

Sample nozzle chart

Nozzle tip charts (Table 5) can be used to determine the factory-calibrated tip capacity and application rates for flat spray tips.

Sprayer calibration

Method A: Using spray tip chart

1. Convert field size to hectares:
   acres × 0.40 = hectares
   e.g., 80 acres × 0.40 = 32 ha.
2. Convert sprayer tank volume to litres:
   gallons × 4.55 = litres
   e.g., 400 gals × 4.55 = 1820 L.
3. Determine application volume per hectare as recommended on pesticide label; application volume is commonly 100 L/ha.
4. Select the most suitable travel speed for your operation, e.g., 10 km/h.
5. Select the spraying pressure, usually between 250 and 300 kPa.
6. Choose nozzle tip with application volume nearest to 100 L/ha using the spray tip chart:
   e.g., 8002 @ 300 kPa @ 10 km/h will deliver about 95 L/ha.
7. Calculate spray required for field:
   number of hectares x spray volume/hectares = litres of solution
   e.g., 32 ha × 95 L/ha = 3040 L.

   Note: Because sprayer tank only holds 1820 L (see Step 2), one tankful delivered at 95 L/ha will spray only

   $$\frac{1820\ \text{L}}{95\ \text{L/ha}} = 19\ \text{ha}$$
8. Mix pesticide, using litres of pesticide per hectare (from container label):
   e.g., if the recommended pesticide rate is = 1.0 L/ha
   amount of pesticide per tank = area × pesticide rate
   19 ha × 1.0 L/ha = 19 L
   Fill the tank half full of water, then add the 19 L of pesticide and complete filling the tank with water.
9. Adjust pressure to 300 kPa, and drive at the selected speed (10 km/h).
10. Calculate amount of pesticide needed to complete field:
    first tank sprayed 19 ha
    amount of field remaining 32 − 19 = 13 ha
    water needed for second tank = 13 ha × 95 L/ha = 1235 L
    pesticide needed = 13 ha × 1.0 L/ha = 13 L.
11. Fill the tank one-third full of water; add the 13 L of pesticide and add water to give a total of 1248 L.
12. Mix and spray balance of field.

Method B: Using formula

The formula method is used when either the application volume (L/ha) for a certain travel speed is not given in the spray tip chart or a chart is not available. It is used also for nonstandard tip spacing or if tips have increased output because of wear. The formula is as follows:

$$\text{L/ha} = \frac{60\,000 \times \text{one tip output (L/min)}}{\text{nozzle spacing (cm)} \times \text{travel speed (km/h)}}$$

Suppose that at a certain transmission gear and throttle setting the speed is 9.1 km/h. As the nozzle tip chart does not give the application volume for 9.1 km/h, use the formula.

Assuming that the spraying pressure is to remain at 300 kPa, the nozzle tip capacity at 300 kPa from Table 4 is 0.79 L/min. Now calculate the application volume from the formula as follows:

$$\text{L/ha} = \frac{60\,000 \times 0.79}{50 \times 9.1} = 104 \text{ L/ha.}$$

If nozzle tip chart is not available, set the sprayer at the desired spraying pressure. Measure output of each nozzle for 1 min. Calculate average output as follows:

$$\text{L/min} = \frac{\text{sum of outputs from all tips (L/min)}}{\text{no. of tips}}$$

Assuming the average output is 0.76 L/min, if the desired spraying speed is 9.1 km/h, then application volume is

$$\text{L/ha} = \frac{60\,000 \times 0.76}{50 \times 9.1} = 100 \text{ L/ha.}$$

Proceed with steps 7 to 12 in Method A.

Electronic monitors

Electronic monitoring systems measure liquid flow and travel speed and display the resulting application volume (L/ha) as a continual digital readout. The operator then adjusts travel speed or spray pressure or both within limits until the desired application volume is displayed. To function properly and accurately, electronic systems must be installed carefully and calibrated according to the manufacturer's instructions.

If the tips are new, a fast and simple way to check the accuracy of a monitor providing application volume is to use a spray tip chart or Table 4. The application rate, speed, and pressure displayed on the monitor should agree with the application rate, speed, and pressure in the chart.

For used tips, compare the displayed output to that measured by the procedure outlined in Method B. The sum of the outputs from all the tips should match the output displayed on the monitor. If the

measured and displayed outputs do not match, adjust the flow sensor calibration number until they do.

For monitors that display application rate (L/ha) only, measure the output of each tip and average them, calibrate the travel speed, and calculate the application rate using the formula:

$$\text{L/ha} = \frac{60\,000 \times \text{average tip output (L/min)}}{\text{nozzle spacing (cm)} \times \text{travel speed (km/h)}}$$

If the calculated application rate (L/ha) does not match the displayed application rate during actual field operation, adjust the flow sensor calibration number. If the calibration number does not match the calculated and displayed application rate, then check the flow sensor and repair it as necessary.

Check the displayed travel speed by the procedure outlined earlier in section on the "Travel speed determination." If the measured travel speed does not match the speed displayed on the monitor, recalibrate or adjust the speed sensor. For greater accuracy, always calibrate the speed sensors in actual field conditions.

Automatic control devices

Automatic control devices work in conjunction with electronic monitors. Instead of adjusting speed and pressure to obtain a desired application volume (L/ha), the operator enters or dials a desired application rate in the monitor. The system then automatically sets the application volume by regulating flow to the booms depending on forward speed by means of a motorized regulating valve in the sprayer bypass line. The operator must maintain a sufficiently constant travel speed so that pressure does not change more than ± 50 kPa from the normal pressure. Operating at low pressures can result in poor spray coverage, whereas high pressures produce small spray droplets that are more subject to drift.

Flowmeter

Flowmeters can be used to measure liquid flow to the booms. The flow rate is usually combined with speed and boom width to determine the application volume. Mount meters in the supply line to the spray booms; the bypass flow must not go through the flowmeter.

Preliminary adjustments and settings

Preliminary adjustments and settings include all the adjustments that are made when the machine is being prepared for use.

Before starting to spray, check wheel bearings and tire inflations and lubricate moving parts as recommended in the operator's manual. Tighten any loose bolts or nuts. Install tips, screens, check valves, and

any other equipment that has been selected. Be sure tips are aligned correctly.

Boom height depends on the spray angle of the tips selected and the target height (Table 3 and Fig. 40). Set the boom at the required height and level it from side to side. Improper height causes nonuniform application.

CHANGING APPLICATION VOLUME

If application volume needs to be changed, three options are available.

Pressure If the change needed is <10%, the pressure or forward speed, or both, can be adjusted to obtain the desired change. A 20% change in pressure results in a 10% change in output. The resulting pressure must still be within the recommended range. However, this method is not good to use, because, to double the flow, pressure must be increased by a factor of 4. Pressure that is too high or too low also distorts spray patterns. High pressure increases the number of small spray particles, which can cause drift.

Speed Changes in travel speed alter application volume. A change in travel speed produces an inverse, proportional change in application volume. This method is practical for small changes in application volume (10–25%). However, avoid excessive speeds for boom stability and safety reasons.

Nozzle tip size If the change needed is >25%, change the tip size to alter the application volume. This change permits use of proper pressure, maintains the spray pattern, and helps control drift. This option is usually the preferred way of changing application volume.

LOADING THE SPRAYER

Water quality

Avoid using ditch, dugout, and slough water if possible, because this water may contain algae, silt, or fine sand particles. The cleaner the water the less sprayer maintenance will be required because tips and strainers are less likely to plug. Dirty water causes rapid wear to pumps and tips. In addition, some pesticides, such as glyphosate, are more effective when used with clean water. Some pesticides have special requirements for water hardness, pH, and so on, which are usually included in the instructions on the label.

Mixing compatibility and stability

Pesticide mixtures

Mixing the pesticide solution thoroughly and carefully is one of the most important steps in good sprayer operation. Incomplete mixing results in varied application rates. Some pesticides can form invert emulsions if mixed improperly. An invert emulsion is a thick, mayonnaise-like mixture that will not spray properly and is difficult to clean out of a sprayer. Pesticides can be mixed in the tank or in a premix container. Specific instructions are given on the label of each pesticide. Follow these instructions carefully, because mixing pesticides in the wrong sequence can prevent otherwise compatible materials from mixing properly.

To mix most pesticides in the tank, add the pesticide to a tank half filled with water. Turn on the agitator and mix thoroughly, then finish filling the tank with water. For other materials, start agitation before adding pesticide and continue until all pesticide–water mix has been used.

If a premix container is used, fill it about half full with water, then add the pesticide. Stir the mixture until it is smooth and uniform, then add it to the water in the sprayer tank. To reduce mixing problems, premix an emulsifiable concentrate with water to form an emulsion, or premix a wettable powder with water to form a slurry. Then add the premix to a partially filled, well-agitated spray tank.

When adding pesticide or premix to the tank, use a sturdy ladder or the steps on the sprayer. Do not stand on a tire, parts of the frame, boxes or other supports. If you were to slip, you could spill pesticide on yourself, resulting in hazardous personal exposure.

Some pesticides are available only as wettable powders because they are difficult or expensive to produce as liquids. Wettable powders are effective, but their application requires proper agitation equipment. The newer model sprayers are generally able to apply wettable powders without problems, but older sprayers may need extensive modification. Worn sprayer pumps may have insufficient flow to provide proper agitation. To ensure sufficient agitation to keep the powder in suspension, install a mechanical or hydraulic agitator in the sprayer tank. The paddle-type mechanical agitator is best, but jet agitators are quite satisfactory if, for every 100 L of tank size, pump output provides 3–6 L/min, in addition to the requirements for supplying the booms. Larger tanks will require two or more agitators.

Jet agitators may be equipped with various sizes of orifice discs, depending on the amount of surplus pump capacity. Naturally, the larger orifice sizes provide more agitation, but if too large an orifice is selected, the pump may not be able to supply sufficient volume. Determining the best orifice size may require some trial and error, although charts are provided with the agitator so that a suitable first selection can be made.

To avoid plugging with wettable powders, all strainers in the sprayer system must be the screen or slotted type and not finer than 50 mesh. Tips of stainless steel, hardened stainless steel, ceramic, or nylon are required for wettable powders because the powder acts as a fine abrasive and rapidly erodes brass or aluminum nozzles.

Follow a proper procedure for adding wettable powders to the tank to ensure that the powder goes into suspension, rather than forming lumps. Start by premixing the material with water in a pail. Fill half the sprayer tank with water and turn on the agitator. Slowly pour the slurry into the tank. If making a tank mix, add the other pesticide, fill the remainder of the tank with water and begin spraying. Do not leave wettable powders standing in the tank. Once they settle to the bottom it is difficult to get them back into suspension.

Without the proper equipment and procedures do not use wettable powders, because their application will be a source of frustration and the results will be disappointing.

Note: Do not confuse wettable powders with soluble powders. Soluble powders truly dissolve in water, they do not remain as a suspended solid. Soluble powders require no special handling, other than a little time and agitation to dissolve them; they will not settle out of the solution.

Pesticide mixtures with fertilizers

Some pesticides are registered for tank-mixing with fertilizers. Always check the label before using a tank mix, and only use tank mixes that are registered.

Storage time in sprayer tank before application

Consult the label for storage times before application. Generally, apply pesticides as soon as possible after mixing and do not leave them sitting overnight. After mixing, keep wettable powders agitated continually until application is completed.

TRANSPORTING SPRAYER TO THE FIELD

Do not transport loaded sprayers any further than necessary. An accident could spill a tankful of pesticides on the road or in a ditch, where containment and cleanup could be very difficult. If agitation of some mixtures is stopped during transport to the field it may be difficult or impossible to obtain adequate remixing.

FIELD OPERATION

End nozzle use

The spray pattern produced by end nozzles is not uniform and is susceptible to drift. Use end nozzles only on fence rows and ditches, and only under low wind conditions.

Misses and overlaps

Avoid misses and overlaps. Repair or replace plugged and worn nozzle tips. Ensure that the tractor drawbar is rigid and has no excessive movement. Stop the boom flow at the headland of the field to prevent overlapping.

Field markers

Field markers are available to aid the operator in preventing misses and overlaps. Disc markers, flag markers, foam markers, spot dye markers, and paper markers are available commercially. Simple devices such as an old light-weight tire casing, dragged at the boom end is satisfactory in some crops. Matching of sprayer and seeding equipment width is another convenient way to eliminate overlaps and misses, by allowing the spray operation to simply follow the tracks produced during seeding.

Suggested method of spraying a field

After spraying around the perimeter, spray fields back and forth. Stop flow to the boom at the headlands to prevent over-application.

Avoid traveling around the field, because during cornering two problems occur. First, part of the corner is missed. Spraying the corners diagonally after completing the field wastes pesticide and may cause serious crop injury.

Second, parts of the boom travel at different speeds causing application rates to vary across the width of the boom. In some cases, part of the boom stops or reverses for an instant, which can cause the crop to be burned.

SPRAYER MAINTENANCE

DISPOSAL OF EXCESS PESTICIDE

Proper planning and measuring is necessary to ensure that there is little excess solution. When a pesticide solution is left over, in some cases one can spray the solution on a summer-fallow field, if available,

at the same rate it was applied to the crop, provided that the pesticide will not adversely affect future crops to be grown on the summer fallow. Excess solution can also be temporarily stored in the original containers in an area inaccessible to children and animals. Familiarize yourself with the specific laws and recommendations in your province regarding the disposal of excess solutions.

SPRAYER CLEANING

Proper maintenance of a field sprayer will increase its hours of trouble-free operation and lengthen its serviceability. Consult the operator's manual for proper maintenance procedures.

At the end of each spraying day, rinse the tank thoroughly with clean water. Then flush clean water through the pump, booms, and nozzles. Remove boom end plugs to thoroughly flush the boom. Check all screens and filters and clean them if necessary. Use compressed air to clean nozzle tips.

A more complete cleaning of the sprayer is required when changing from one pesticide to another, especially when the crop to be sprayed is sensitive to the previous pesticide. There is no satisfactory way to remove completely all traces of any pesticide from a sprayer. Most pesticides are formulated as emulsifiable concentrates, water-soluble concentrates, or as wettable powders. Depending on the type of formulation, procedures for cleaning sprayers are suggested in several provincial sprayer bulletins. Generally, these procedures suggest a thorough rinse with clean water, following an initial washing with either a dilute solution of detergent for sprayers containing residues of emulsifiable concentrates, such as 2,4-D esters; or a dilute solution of ammonia for sprayers containing water-soluble formulations, such as 2,4-D amine. For details of steps involved, check with your provincial department of agriculture. Some pesticides have specific instructions for cleaning the sprayer. Check product labels for specific information on cleaning.

SPRAYER STORAGE

When preparing the field sprayer for storage, follow a five-point checklist:

1. Thoroughly clean the sprayer; drain it completely, especially the filters, pump, pressure regulator, selector valve, gauges, and any other fittings that may retain water.
2. Check the sprayer for worn parts, list all components that need replacement, and order the parts well before the next spraying season.
3. Before winter storage, remove the pump and follow the manufacturer's recommendations for storage.
4. Seal off any openings to prevent entry of dirt, debris, or rodents.

5. Store the sprayer where it will not be damaged by other equipment or livestock. Store polyethylene tanks under cover to prevent possible deterioration by sunlight. Store galvanized steel tanks indoors away from moisture to prevent rusting.

DRIFT CONTROL

TYPES OF DRIFT

Pesticide drift is the movement of pesticide from the intended target to off-target areas. Drift can result in costly crop, insect, or environmental damage in off-target areas. Two types of pesticide drift can occur. First, droplet drift occurs at the time of spraying when smaller droplets remain airborne and are carried downwind. It is the most common and usually the most damaging type of drift. Second, vapor drift occurs following deposition of the pesticide on the crop or soil surface. The pesticide may then begin to evaporate, releasing into the air vapor that drifts downwind for considerable distances. Vapor drift can occur over a period of several days to weeks following application.

Because vapor drift is controlled primarily by the pesticide's volatility, the farmer can do little to reduce it, except to use relatively nonvolatile or low-volatile formulations. Spraying only when a period of cool weather is expected may reduce vapor drift, but normally this measure is not very practical.

Droplet drift, on the other hand, can be controlled by a variety of practical measures. However, some measures taken to reduce droplet drift can result in reduced pest control. Thus, a careful balance must be struck between controlling drift and obtaining adequate pest control.

DROPLET SIZES

In conventional sprayers, droplets are produced by hydraulic pressure. Water under pressure is forced through an orifice and spreads into a sheet of liquid. As the liquid travels from the tip, it breaks into thin sheets called ligules, which in turn break into droplets. Large droplets may break into small droplets before the target is reached.

The most desirable droplet size for any spray application depends on the pesticide being applied, the nature of the spray target, and the environmental conditions at the time of application. Insecticides and fungicides normally require very small droplets (<150 µm) to maximize the surface contact area. Postemergence herbicides usually require droplets of 150–400 µm in size. Tiny droplets (<100 µm) are subject to off-target drift, whereas larger droplets (>650 µm) usually roll or bounce off plant surfaces. Coverage with soil-applied herbicides can be less specific as to drop size; larger droplets result in reduced spray drift.

Because all spray tips and applicators produce a range of droplet sizes, it is not possible to describe the sizes produced with a single number. Several ways are used to describe the range of droplet sizes, but probably the easiest method to understand is to plot the droplet diameters versus accumulated volume percentage (Fig. 49). In the example shown, 95% of the spray volume consists of droplets ≤600 µm, 50% consists of droplets ≤385 µm, and 3.5% consists of droplets ≤200 µm. The 50% of volume point is referred to as the volume median diameter (VMD), which in this example is 385 µm. This value is that most commonly used to designate "average" droplet size.

The droplet sizes produced by a tip are affected by orifice design and size, by spraying nozzle angle, and by the liquid pressure (Fig. 50). For any given type of tip, larger-orifice tips produce larger droplets, and the wider the tip angle, the smaller the droplet size. Table 12 shows the effect of orifice size on the droplet sizes produced by several flat spray tips at an operating pressure of 275 kPa.

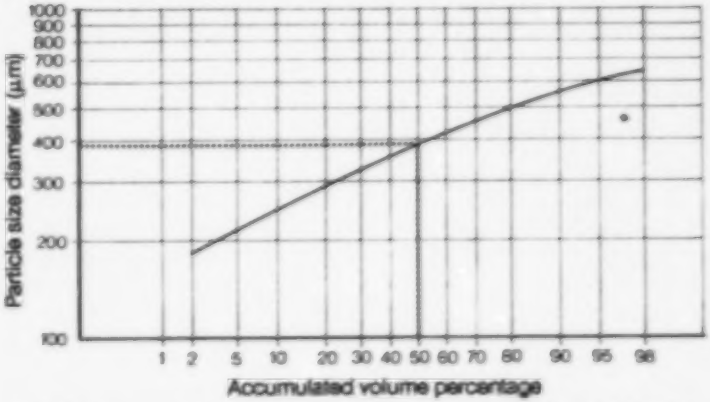

Fig. 49 Accumulated volume percentage versus particle size diameter.

Table 12 Effect of tip orifice size on droplet volume median diameter (VMD)

Tip size	% of volume in droplets <200 µm at 275 kPa	VMD (µm)
8001	6	355
8002	3.5	385
8004	2	430

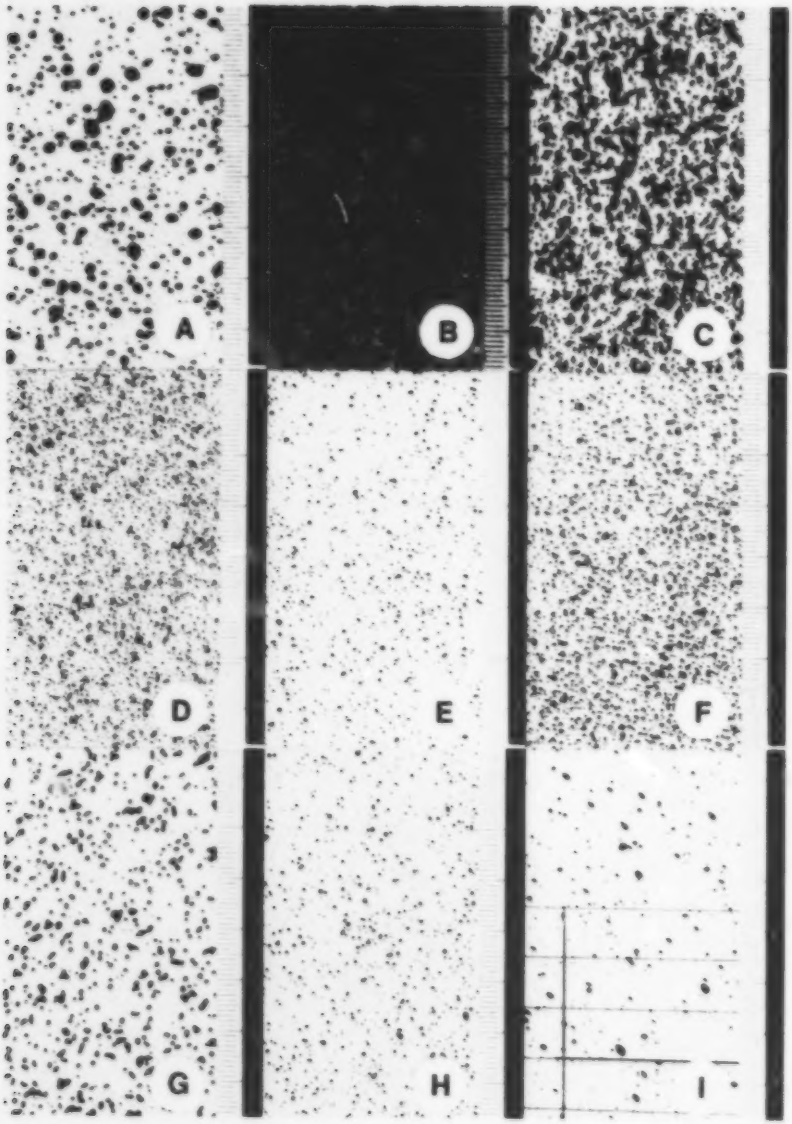

Fig. 50 Spray deposits produced by various tips and applicators: *A*, Raindrop RD-1, 210 kPa, 110 L/ha, nozzle position horizontal back-facing; *B*, 11002, 280 kPa, 110 L/ha; *C*, 8002, 280 kPa, 110 L/ha; *D* 8001, 280 kPa, 50 L/ha; *E*, 730077, Spray Coupe, 280 kPa, 55 L/ha; *F*, 650067, 280 kPa, 55 L/ha; *G*, spinning disc (Micromax), 280 kPa, 40 L/ha 2000 rpm; *H*, spinning disc (Micromax), 280 kPa, 40 L/ha 5000 rpm; *I*, aircraft Piper Pawnee D10-45, 170 kPa, 28 L/ha.

CONTROLLING DRIFT

Environmental factors

The best way to reduce droplet drift is to spray in winds < 15 km/h (but not in completely calm air). Avoid applying pesticide in winds that exceed 20 km/h, especially near the downwind field edge. Also, generally the spray deposit pattern is worsened in winds > 25 km/h. Winds are usually lightest in the morning and near sunset. Many pesticides perform best when applied in the cool, humid conditions often present in the morning and near sunset.

Humidity and air temperature affect droplet drift by controlling the rate at which airborne droplets evaporate and become smaller and more drift prone. When using a water-based pesticide solution, spraying under humid conditions is better for drift control than spraying under dry conditions at the same temperature. The higher the temperature the faster the rate of evaporation and the greater the risk of drift.

Air temperature is also important because it varies with height near the ground. During the night and until about 1 h after sunrise, air near the ground is often cooler and more stable than the air above it, and a temperature inversion exists. The situation where mist hangs over a lake or pond around sunrise is a good example of a temperature inversion. Spraying during a temperature inversion can produce a cloud of driftable droplets that remains concentrated near the ground. Avoid spraying during temperature inversions, especially near sensitive areas.

Operational factors

Spray volume

The use of 02 size or larger tips for pesticide applications is recommended for drift control. Increasing the spray volume by using larger tips can reduce drift because these nozzles produce a higher proportion of large droplets and a lower proportion of small driftable droplets. However, spraying larger droplets results in poor on-target spray coverage and also requires large amounts of water. The 02 size tip represents a good compromise between spray coverage and drift control. Use larger-orifice tips only where uniform surface coverage is not essential.

Reduced pressure

One way of reducing droplet drift is to create a coarser spray by reducing the pressure at the nozzle. However, this method is seldom acceptable with ordinary flat spray nozzles, because the pattern is adversely affected by operating below the recommended pressure. In addition, a large reduction in pressure is required to alter droplet size significantly. The use of extended range flat spray nozzles (designated LP, LFR, or XR) allow for low operating pressures while retaining an acceptably uniform spray pattern.

Tip height

Tip spray angle affects droplet drift by affecting droplet size and the boom height required for proper spray overlap. The smaller the tip angle, the greater the mean droplet size (VMD). For example, operated at 275 kPa, a 110° tip has a VMD of about 300 µm, whereas an 80° tip has a VMD of about 400 µm and a 65° tip has a VMD of about 475 µm. However, the smaller the tip angle, the greater the boom height required to obtain proper spray overlap (Fig. 40, Table 3). The higher the boom height, the more vulnerable the spray pattern is to wind effects. Thus, 65° tips produce larger droplets that are more resistant to drift but require a higher boom, which makes the spray more prone to drift. The 80° tips are probably the best compromise between height, droplet size, and drift.

Speed of travel

Speed of travel also has a bearing on spray drift, especially on rough terrain. Boom bounce caused by excessive speed can increase drift and result in poor spray distribution, leaving areas of crop damage and poor pest control. Spray drift is also increased by a combination of the wind and the turbulence created by the moving sprayer, a feature that is most obvious for high-speed spraying vehicles like the Spra-Coupe and aircraft. These sprayers produce greater off-target drift and less on-target deposits than conventional groundrigs, because of a combination of factors, such as higher release heights, smaller droplets, and speed of travel.

Boom and nozzle shields

More recently, some trailer-mounted sprayers can be equipped with shields that protect the spray pattern from wind. The shields may cover either the whole boom (Fig. 51) or individual nozzles as cones (Fig. 52). Shields that cover the whole boom are available in a variety of forms, whereas the cones are available in one size to fit up to 110° spray tips. The advantage of shields is that they reduce spray

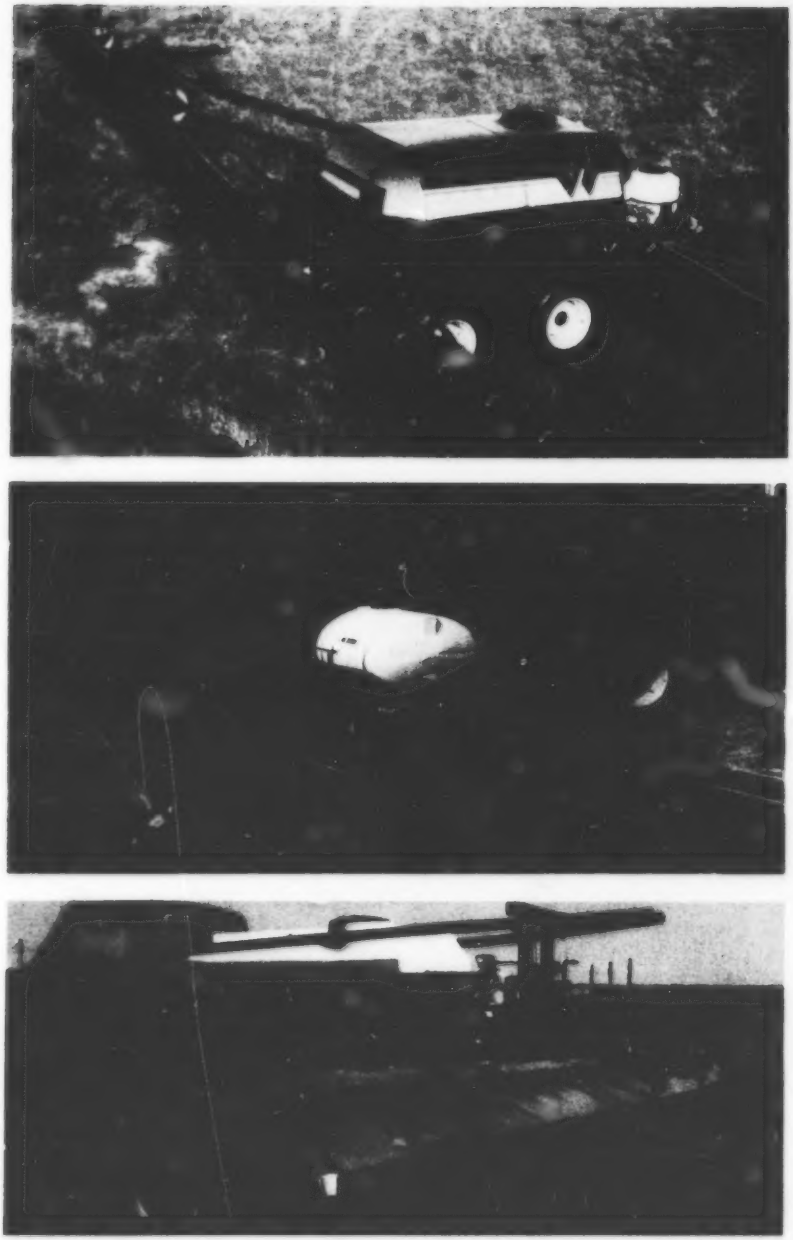

Fig. 51 Sprayers with shields on booms.

Fig. 52 Cone-shielded sprayer.

drift, especially under windy conditions, thus extending the time available for spraying. Recent studies have shown that shields do not completely eliminate drift, even at low wind speeds, but they help to reduce spray drift. These same studies indicate that the deposit pattern of some shielded sprayers may show more variation than unshielded sprayers, especially under conditions of high wind.

Chemical and physical factors

As stated earlier, the only practical method of reducing vapor drift is to use relatively low-volatile or nonvolatile pesticide formulations. Use these formulations especially if damage-sensitive areas exist near the area to be sprayed.

Several additives that coarsen the spray and reduce drift have been introduced onto the market. Foaming agents, for example, reduce drift but adversely affect the spray deposit pattern. Check the pesticide label for any potential use of these additives.

Surfactants may be added to the formulation to improve the sticking and spreading of the droplets on foliage. Claims have been made that surfactants reduce the evaporation rate from airborne droplets and thus reduce drift. However, tests have not yet shown that this reduction does in fact occur.

The use of oils rather than water as the carrier solvent would similarly help in controlling drift, but their expense prohibits their widespread use, especially for groundrig application.

SAFETY AND HEALTH CONCERNS

Safety and health should be of prime importance to anyone working with pesticides. Although most pesticides are considered safe if handled properly, the long-term effects of exposure to pesticides are unknown. As several pesticide safety guides have been published recently, this section mentions only briefly the basic precautions that you should take to protect your safety.

CONTAINER HANDLING AND DISPOSAL

Container-rinsing procedure

Clean all containers by triple or pressure rinsing. Pressure rinsing for 30 s is just as effective as triple rinsing and renders the containers useless for other uses by automatically puncturing them. Puncture all pesticide containers before disposal.

On-site disposal

On-site disposal involves burying triple-rinsed containers at least 30 cm deep in a clay or loam soil. Crush containers and break glass bottles before burying them in an uncropped area away from wells, ponds, streams, and livestock feeding areas. The burial site should have no run-off from the site. The water table should be at least 3 m from the surface. Backfill and compact the site to retard seepage, and mark and record the area. Check provincial regulations prior to disposal.

Regional and local disposal

In many provinces, public sites for disposal of pesticide containers are available. These disposal sites enable farmers to remove pesticide containers from their property, which is easier than burying them. The environmental acceptability of these sites depends on the delivered containers being triple or pressure rinsed before delivery. In this regard, the disposal program works on the honor system. Stack containers delivered to these sites neatly on their sides to prevent rainwater from entering them and pesticide residues from escaping them. Check for municipal regulations regarding these sites.

GUIDELINES FOR MINIMIZING EXPOSURE DURING HANDLING AND APPLICATION

Pesticide container label information

To help pesticide users know what safety precautions to take, symbols and signal words are used on pesticide labels to indicate the primary hazard and the degree of hazard (Table 13). Pesticides considered nonhazardous require neither symbols nor signal words. Also included on the label are safety precautions to be taken to minimize exposure, and specific first-aid steps to be administered in case of accidental exposure. *Always read the label before using a pesticide*!

Protective equipment and clothing

It is impossible for operators to completely avoid exposure to the pesticides they are applying. Exposure can occur while transporting the pesticide, tank filling and mixing, rinsing the containers, spraying, maintaining the sprayer, and storing pesticides. Exposure can involve contact with pesticide vapors and aerosols, the concentrated pesticide formulation in a liquid, powder or granular form, and the spray mixture itself. Because pesticides are more concentrated before they are diluted in water, the greatest exposure is likely to occur when handling the pesticide itself, such as when pouring it into the spray tank.

Exposure can occur in four ways: ocular exposure, oral exposure, inhalation exposure, and dermal exposure. Proper protective equipment to minimize exposure is available through safety equipment suppliers, farm supply stores, elevators, and some hardware stores. Besides adopting adequate protective measures, operators must also adopt a responsible attitude towards pesticides.

Ocular exposure

Exposure of the eyes can result in permanent vision impairment or blindness. Avoid exposure by wearing goggles whenever you handle pesticides. Do not wear gas-permeable and soft contact lenses while handling pesticides, because they may absorb and concentrate pesticides next to the cornea. Although eye glasses offer some protection, they do not protect on all sides as do goggles. Goggles are now designed to be worn comfortably over eye glasses and can be purchased with specially treated lenses or covered vents to reduce fogging. The straps on goggles should be made of plastic or rubber so they can be readily washed. Keep a supply of fresh water in a clean container always within easy reach to be used as an eye wash solution in case of accidental exposure.

Table 13 Primary hazard symbols, precautionary symbols, and corresponding signal words

Primary hazard symbol	Signal word	Precautionary symbol	Degree of hazard	Signal word
	POISON			
			high	DANGER
	CORROSIVE			
			moderate	WARNING
	FLAMMABLE			
			low	CAUTION
	EXPLOSIVE			

Oral exposure

Always avoid eating, drinking, and smoking while handling pesticides. Never carry food or cigarettes on your person while working with pesticides. Good personal hygiene is the best way to prevent oral exposure. Many farmers carry a container of soapy or clean water with them so they can wash their hands prior to eating or smoking. Other practices that can lead to oral exposure are blowing out plugged tips with the mouth and drinking from the hose used to fill the spray tank. Always avoid these practices!

Inhalation exposure

Although it helps to remain upwind of pesticides, minimize inhalation exposure to pesticide vapor or powder by wearing a chemical cartridge respirator. This device covers the mouth and nose to prevent the inhalation of pesticides. These chemical cartridge respirators have a full face piece that protects face, head, and eyes. Airstream respirators are also available.

Dermal exposure

Most exposure to pesticides occurs through the skin. It is important to understand not only that pesticides can be absorbed directly through the skin, but also that different parts of the body absorb pesticides at different rates. The scrotal area, ear canal, forehead, and scalp are particularly vulnerable to absorbing pesticides.

Clothing is the main defense against dermal exposure and protective clothing is recommended for all areas of the body. Besides being difficult to wash, materials such as leather absorb pesticides and trap them near the skin. Therefore, do not wear leather garments such as boots or gloves while handling pesticides.

Head If an airstream-type respirator is not used, a waterproof, wide-brimmed hat or hard hat equipped with a plastic sweat band is recommended. Baseball-type caps offer little protection and, if they become contaminated, may even continue to expose the head to the pesticide or pesticides.

Hands Always protect the hands as being the most likely area to contact pesticides. Gauntlet-type or elbow-length gloves made of unlined neoprene or nitrile are recommended, as they protect the wrist area as well. Fold out the tops of the gloves as a cuff to prevent pesticides from running onto the arms when raised. Wash the outside of the gloves before removal; provided that they are unlined, both the insides and outsides can be thoroughly washed after use.

Feet Always wear knee-length boots made of rubber or neoprene. These can be purchased with safety toes and sole plates for added protection.

Body Wear water-repellent outer clothing made of rubber or synthetic polymer over trousers and a long-sleeved shirt. Unlined rubber garments are available as jackets, pants, and aprons. These are heavy and warm to wear but can be washed and used many times. Synthetic polymers usually come as overalls and are much lighter to wear; some types are disposable and should not be re-used. Either bury or place in a plastic bag contaminated, disposable garments and dispose of them at a municipal waste disposal site, if permitted.

Fabric coveralls made of a tightly woven material such as denim offer some protection; use them in conjunction with a rubber or synthetic polymer apron worn over the groin area. Launder fabric garments separately from uncontaminated clothing at the end of each day's spraying. Never wear the clothing that is worn while spraying at other times.

Regardless of the choice of material, coveralls should be completely buttoned or zippered, with the sleeves rolled down over the gloves. Wear pant legs outside the boots and hold them snugly in place with rubber bands.

When you have finished spraying for the day, take a shower as soon as possible. The longer a pesticide remains on your skin, the greater the amount that your skin will absorb. When showering, use plenty of soap and shampoo and pay special attention to your hair and fingernails.

TROUBLESHOOTING CHECK LIST

Sprayers can fail to operate properly because of breakage, corrosion, abrasion, blockage, and pumps that run dry. Good equipment, careful operation, and proper maintenance will reduce the number of breakdowns and increase the life span of your sprayer. However, problems will occur occasionally. Listed below are the more common problems encountered and their possible causes and remedies.

PROBLEM	POSSIBLE CAUSE	REMEDY
Insufficient pressure	1) Regulator malfunction; improperly set or stuck.	1) Clean and adjust regulator.
	2) Strainer or suction line plugged.	2) Thoroughly clean strainer and clear suction line.
	3) Cracked or porous suction hose.	3) Replace hose.
	4) Worn pump.	4) Replace or recondition pump.
	5) Pump starving.	5) Check for collapsed suction line, plugged filter, shutoff valve closed or too small; no solution in the tank.
	6) Excessive agitation.	6) Increase pump size or reduce flow through agitator.
	7) Faulty gauge.	7) Replace gauge.
	8) Excessive tip wear.	8) Replace nozzle tips.
Excessive pressure	1) Pressure regulator improperly set or stuck.	1) Adjust pressure regulator.
	2) Pressure regulator too small.	2) Install larger regulator.
	3) Bypass hose plugged or too small.	3) Unplug hose or replace it with a larger one.
	4) Faulty gauge.	4) Replace gauge.
	5) Agitator on bypass line.	5) Install separate agitation line.
Pressure gauge needle jumps excessively	1) Gauge too sensitive.	1) Replace gauge and mount a damper between gauge and pump.
	2) Pump starving.	2) Check for restriction on inlet side of pump.

	3) Air leaking into system.	3) Check for air leaks and repair.
	4) Pulsation damper waterlogged.	4) Drain water from damper.
	5) Pulsation damper set at incorrect pressure.	5) Set air pressure as per manufacturer's recommendation.
Tip plugging	1) Nozzle screen too coarse.	1) Replace with proper size mesh.
	2) Dirty water or foreign material in the tank.	2) Drain tank and clean thoroughly; check suction screen for holes.
	3) Pesticide (wettable powder) not properly mixed.	3) Increase agitation.
	4) Boom filled with foreign material.	4) Remove plugs at ends of boom section and flush with water.
Poor spray pattern	1) Booms too low.	1) Raise boom or rotate ahead or back slightly.
	2) Pressure too low.	2) Check pressure at boom end; pressure should be within 10–15 kPa of main gauge; if not, check fittings and hoses for restrictions.
	3) Nozzle tips worn or damaged.	3) Replace nozzle tips.
	4) Nozzle screen plugged.	4) Clean or replace screen.
	5) Foreign material in nozzle tip.	5) Clean tip with air blast.
Visible spray drift	1) Spray too fine.	1) Reduce pressure, use larger nozzle tips.
	2) Boom set too high.	2) Lower boom and angle forward or back.
	3) Too windy.	3) Quit spraying.
Horizontal boom swinging	1) Loose hitch between sprayer and tractor.	1) Tighten hitch.
	2) Loose hitch pin.	2) Use ball-type hitch.
	3) No braces.	3) Install horizontal braces on boom.
Excessive vertical boom whip	1) No boom wheels.	1) Install boom wheels.
	2) Rough field.	2) Slow down.

ADDITIONAL INFORMATION

The federal government, several provincial governments, and the pesticide industry publish guidelines and bulletins on safety and to assist in spraying operations. Some of these guidelines are the following:

Pesticide safety, Agriculture Canada Publication 1825E (or F)
Pesticide handling, A Safety Handbook (Health & Welfare Canada)
Guide to crop protection in Alberta (Alberta Agriculture)
A guide to field sprayer operation (Saskatchewan Agriculture and Food)
Field sprayers (Manitoba Agriculture)
Field weed sprayers (Ontario Ministry of Agriculture and Food)
Orchard sprayers (Ontario Ministry of Agriculture and Food)
Field sprayer calibration (Ontario Ministry of Agriculture and Food)
Pulvérisateur à rampe—Guide d'utilisation (Quebec Agriculture)
Grower pesticide safety course manual (Ontario Ministry of Agriculture and Food)
Farm chemical safety is in your hands (Crop Protection Institute of Canada)

APPENDIX

Provincial legislations regarding pesticide use are as follows. Readers are encouraged to become familiar with the pesticide control act in their province.

British Columbia—Pesticide Control Act Regulation, 1981 (consolidated 1984).
Alberta—Agricultural Chemicals Act, 1980 (consolidated 1984).
Saskatchewan—The Pest Control Products (Saskatchewan) Act, 1973 (amended 1976).
Manitoba—The Clean Environment Act (consolidated 1985).
Ontario—Pesticides Act, 1980 (revised 1985).
Quebec—Pesticides Act, 1987.
New Brunswick—Pesticides Control Act, 1982 (amended 1983).
Nova Scotia—Environmental Protection Act.
Prince Edward Island—Pesticides Control Act, 1983 (amended 1988).
Newfoundland—The Pesticides Control Act, 1983.
—The Pesticides Control Regulations, 1984.

CONVERSION FACTORS FOR METRIC SYSTEM

Imperial units	Approximate conversion factor	Results in	
Length			
inch	× 25	millimetre	(mm)
foot	× 30	centimetre	(cm)
yard	× 0.9	metre	(m)
mile	× 1.6	kilometre	(km)
Area			
square inch	× 6.5	square centimetre	(cm^2)
square foot	× 0.09	square metre	(m^2)
square yard	× 0.836	square metre	(m^2)
square mile	× 259	hectare	(ha)
acre	× 0.40	hectare	(ha)
Volume			
cubic inch	× 16	cubic centimetre	(cm^3, mL, cc)
cubic foot	× 28	cubic decimetre	(dm^3)
cubic yard	× 0.8	cubic metre	(m^3)
fluid ounce	× 28	millilitre	(mL)
pint	× 0.57	litre	(L)
quart	× 1.1	litre	(L)
gallon (Imp.)	× 4.5	litre	(L)
gallon (U.S.)	× 3.8	litre	(L)
Weight			
ounce	× 28	gram	(g)
pound	× 0.45	kilogram	(kg)
short ton (2000 lb)	× 0.9	tonne	(t)
Temperature			
degrees Fahrenheit	(°F − 32) × 0.56 or (°F − 32) × 5/9	degrees Celsius	(°C)
Pressure			
pounds per square inch	× 6.9	kilopascal	(kPa)
Power			
horsepower	× 746	watt	(W)
	× 0.75	kilowatt	(kW)
Speed			
feet per second	× 0.30	metres per second	(m/s)
miles per hour	× 1.6	kilometres per hour	(km/h)
Agriculture			
gallons per acre	× 11.23	litres per hectare	(L/ha)
quarts per acre	× 2.8	litres per hectare	(L/ha)
pints per acre	× 1.4	litres per hectare	(L/ha)
fluid ounces per acre	× 70	millilitres per hectare	(mL/ha)
tons per acre	× 2.24	tonnes per hectare	(t/ha)
pounds per acre	× 1.12	kilograms per hectare	(kg/ha)
ounces per acre	× 70	grams per hectare	(g/ha)
plants per acre	× 2.47	plants per hectare	(plants/ha)

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